NINJA VS VIKING: HISTORY'S DEADLIEST WARRIORS

HOW IT WORKS

ONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

MIND TRICKS
DISCOVER HOW YOUR SENSES CAN BE FOOLED

HI-TECH FITNESS
How virtual reality games will get you fit

CLIMATE CHANGE MYTHS BUSTED

FIND OUT WHAT IS REALLY HAPPENING TO OUR PLANET

IS GLOBAL WARMING OUR FAULT?

IS CLIMATE CHANGE A CONSPIRACY?

SEEK & DESTROY
The drones that will help clear minefields

WON'T WARMER WEATHER BE BETTER?

CASSINI'S GRAND FINALE
WHAT'S IN STORE FOR THE SATURN PROBE'S LAST MISSION?

BIRD BRAINS
How do woodpeckers avoid head injuries?

VITAMINS & MINERALS
Essential nutrients and where to find them

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ISSUE 97

WELCOME

The magazine that feeds minds!

"Cassini has almost single-handedly revolutionised our knowledge of Saturn and its moons..."

Cassini's Grand Finale, page 60

Meet the team...

Charlie
Production Editor
Unless it's all just a clever illusion, you will find out how your brain can be tricked in to seeing things that aren't really there on page 36. The mind is a wonderful but fallible thing.

Jack
Senior Staff Writer
Did you know that Gurkhas must be able to do 70 sit-ups in two minutes to be considered for selection in the British Army? Meet history's deadliest warriors on page 72!

James
Research Editor
It's important to include vitamins and minerals in our daily diet, but sometimes that's easier said than done. Head over to page 44 to discover which foods have the nutrients we need to keep us healthy.

Duncan
Senior Art Editor
The climate change debate continues to rumble on. Find out what really is happening to our planet at the moment on page 12. No 'alternative facts' guaranteed!

Laurie
Assistant Designer
Future fitness tech has got me excited this month. Flick to page 50 to learn about the smartest technology keeping us healthy in 2017 and the new inventions that look set to revolutionise your daily workout.

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There's a lot of controversy around the idea that human activity can affect the planet's climate. Despite all the scientific evidence, there are many misconceptions about the causes and effects of global warming, so this month we aim to bust some of the most persistent climate change myths.

About 1.2 billion kilometres away from the fragile blue marble we call home, NASA's Cassini probe is gearing up for it's grand finale. In this last hurrah, it will sweep between Saturn and its rings before plummeting in to the planet itself. In our space feature, we celebrate the achievements of the record-breaking Cassini-Huygens mission.

Over in the science section, prepare to have your mind boggled by optical illusions as we find out how our senses can be fooled so easily. Also discover how virtual reality games and artificially intelligent personal trainer systems will soon be helping us get fit.

Enjoy the issue!

Jackie **Jackie Snowden**
Deputy Editor

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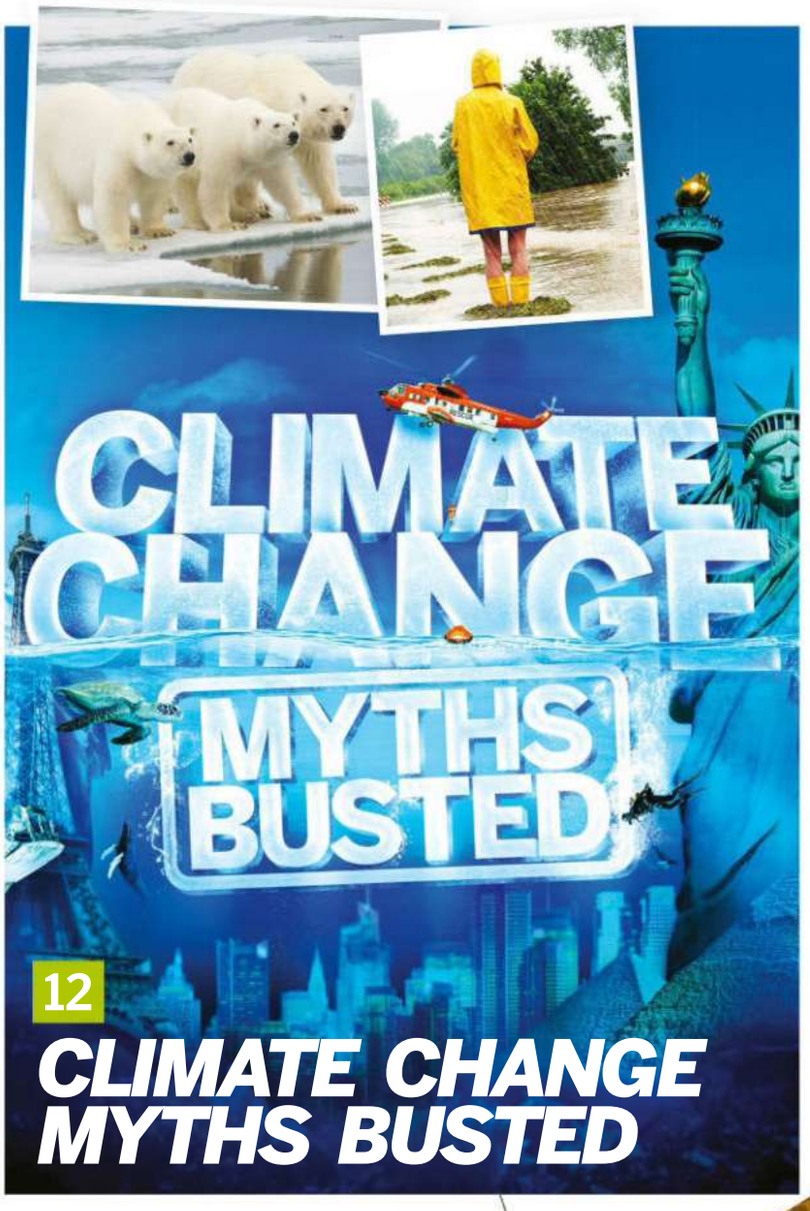


Meet the experts...

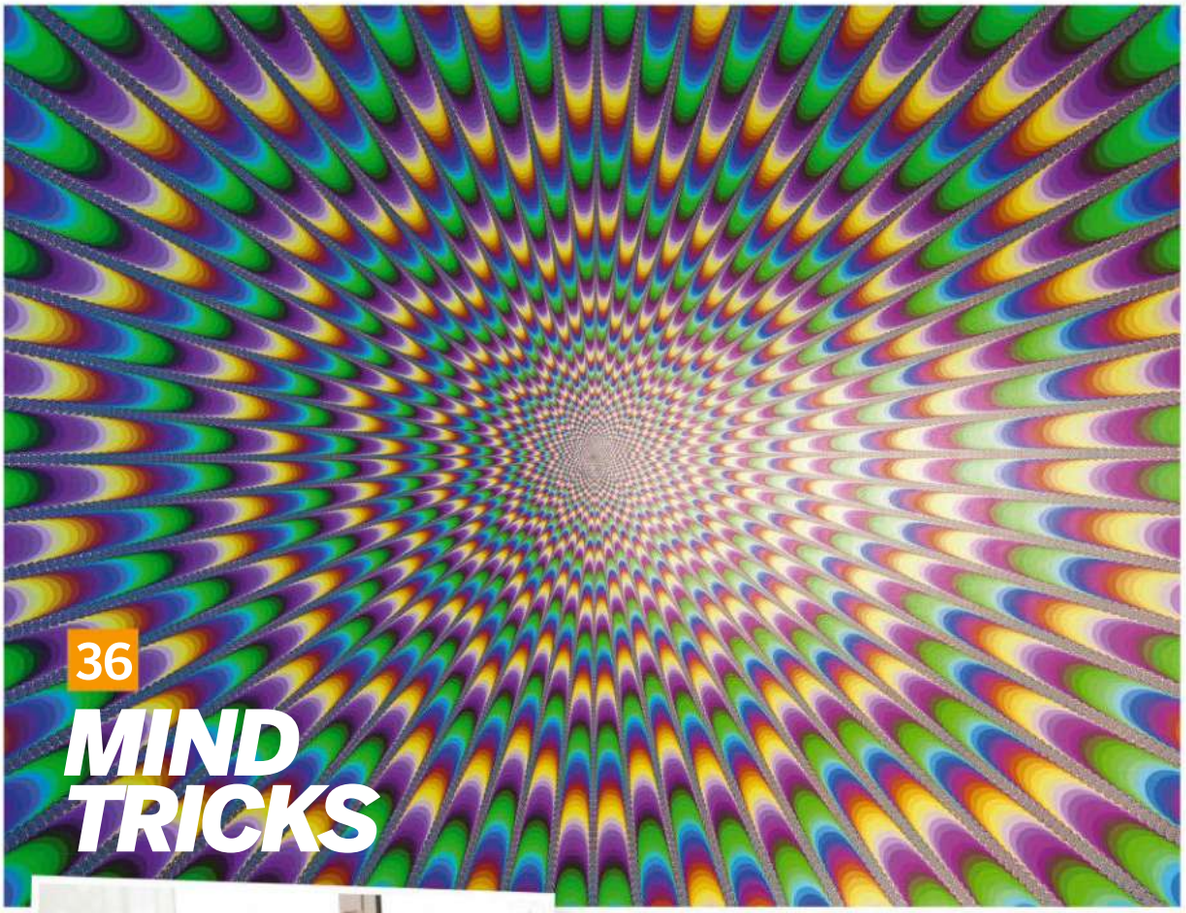
Stephen Ashby
Steve takes a trip to the gyms of the future to find out what's in store for fitness tech over the next few years. He also takes a peek inside the latest Apple MacBook Pro.

Laura Mears
This month, Laura busts some common myths and misconceptions about climate change to try and get to the bottom of this controversial topic. Head to our cover feature on page 12.

Jo Stass
Jo's brain has been well and truly boggled by mind-bending illusions after researching our science feature. Find out how to fool your brain into thinking your nose is really long, or a rubber hand is your own on page 36.

Jonny O'Callaghan
In our space feature, over on page 60, Jonny reveals what's in store for Cassini's Grand Finale, and celebrates what the epic mission has taught us in its 13 years at Saturn.

Mike Simpson
In this issue, Mike gets us revved up about the cutting-edge tech that could make motorcycles the future's top mode of transport. He also explains what's happening behind a car's dashboard.



REGULARS

HIGH HOPES FOR GOOGLE'S BALLOON INTERNET PROJECT

Project Loon receives a major boost in its mission for global internet connectivity

Currently four billion people on Earth don't have access to the internet. Google's Project Loon is seeking to change this, and recent developments in machine learning algorithms have brought its goal one step closer. The project centres around a network of balloons sent 20 kilometres into the stratosphere. Each one is solar-powered and makes use of air currents to move. The breakthrough will enable weather systems to be predicted much further in advance, which means the balloons can be efficiently moved into different layers of the stratosphere, allowing access to different wind speeds and directions.

This will enable greater control of the balloons' positions, allowing them to be stationed in specific areas, rather than continuously moving across the globe as previously planned. As well as reducing costs, fewer balloons will be needed, making the whole project easier to manage.

Project Loon will work by transmitting a wireless signal from the ground up to the balloon. The balloon then relays the signal down to provide an unconnected region with internet access, with each balloon having a coverage area of 5,000 square kilometres. The balloons' locations can be tracked by GPS to ensure they can reach the areas that require coverage. It is hoped this recent algorithm advancement will allow the innovative project to really take off.

When inflated, each balloon is around the size of a tennis court

Material
The balloons are made from polyethylene, which helps protect them from UV radiation and extreme temperature changes.

"Over half the global population don't have access to the internet"

Transceivers
The internet connectivity is transmitted from this part of the balloon down to the ground.

Solar panels
Solar panels power the system during the day and also charge a battery so it can continue to function at night.

Flight capsule
This is where the control system and avionics software is located, which allows the balloon to be monitored 24 hours a day.

The new machine learning technology will make the balloons much more effective

10,000-YEAR-OLD MICROBES DISCOVERED IN CRYSTAL CAVE

Ancient organisms have been found encased in a cavern underneath a Mexican mountain range

Deep in the Naica Mountains, one cave plays host to remarkable ancient life forms. Encased in giant gypsum crystals, the microbes are at least 10,000 years old, with some estimates placing them at 50,000 years of age. The subterranean cavern is known as the Cave of Crystals. Temperatures here can reach up to 60 degrees Celsius, so when venturing underground scientists are forced to wear special suits that prevent contamination and keep them cool with ice packs placed all over the body.

Despite this harsh environment, the organisms were successfully revived by scientists both on site and under laboratory conditions. The remarkable survival of these hardy microorganisms is down to their ability to chemosynthesise. Using carbon dioxide, water and chemical nutrients in rocks like iron and manganese as a source of energy, the microbes are able to generate enough energy to exist, even without sunlight. The organisms within the crystals were different to those found on the walls of the cave and were discovered in a dormant state encased in pockets of fluid. After taking them away for study, scientists found that they were genetically distinct from any other documented organism on Earth.

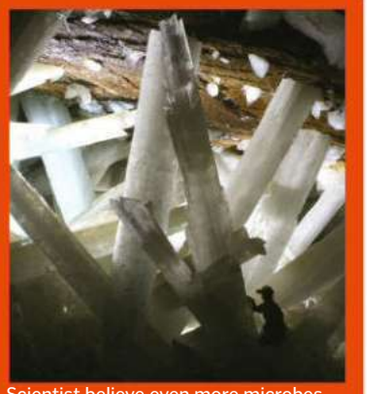
Within the huge gypsum crystals were 40 different microbe strains, as well as a number of different viruses. The findings suggest that microbial life can withstand more unforgiving conditions than previously believed and could change theories on how microbial life first began.

The cave's largest crystals are 12 metres in length and weigh 55 tons

The Cave of Crystals

The microbes were found in the Cave of Crystals, a cavern first discovered in 2000. Miners stumbled across the extraordinary cave by accident after draining the surrounding area for silver mining operations. What they found inside were some of the largest crystals ever uncovered. Over a metre thick, they are scattered across the cave and have grown to these enormous sizes over thousands of years.

Anyone who goes into the cavern has to wear a special suit equipped with a breathing and cooling system to withstand the intense heat and humidity. The mask can be taken off for around ten minutes before a human would fall ill. Now that the mining operations have ceased in the area, the Cave of Crystals has naturally flooded once again and for now has become unreachable.



Scientist believe even more microbes could be buried deep inside the Earth

NEWS BY NUMBERS

10 trillion years
The life expectancy of the dwarf star, Trappist-1

15m
The diameter of the largest pancake ever made

40 km/h
How much faster at cornering F1 cars in the 2017 season could be than their predecessors

13 million
Pints of Guinness consumed worldwide on St Patrick's Day

Earth-size exoplanets revealed

NASA has uncovered a record-breaking star system

The first system with seven Earth-sized exoplanets around a single star has been found by NASA's Spitzer Space Telescope. Located 40 light years away and orbiting the ultra-cool dwarf star, Trappist-1, three of the rocky worlds exist within the designated 'habitable zone', meaning they could harbour liquid water. The planets are clustered more tightly together than the celestial bodies in our Solar System, and all orbit closer to their local star than Mercury does to our Sun. Research is currently underway to test these planets for any evidence of an atmosphere.

Trappist-1 is named after an optic robotic telescope in Chile

A modern study stated that 15 million jobs could be lost to automation in the UK in the future

Rolls-Royce to introduce crewless ships

If successful, these vessels could cut sea transport costs by up to 20 per cent

In a progressive move, Rolls-Royce is working towards making all seaward vessels autonomous. The ships will be controlled remotely from land using virtual decks that can control several vehicles at a time with the help of drones and virtual reality cameras. Starting with ferries before moving on to cargo ships, it's hoped the development will increase profits, but there are questions over its feasibility. Crewless ships would be easy prey for pirates, plus there are concerns over the effect it will have on jobs.

Woolly mammoth hybrid to be brought back within two years

A new genetic project will attempt to resurrect the elephant's ancestor

The woolly mammoth hasn't roamed the Earth for over 4,000 years, but it could be making a comeback. Using DNA extracted from frozen mammoths, scientists will implant genes into an elephant embryo using CRISPR gene editing. This will create a hybrid with all the physical features of a mammoth, from its warm coat to its 'antifreeze' blood. Early tests have been positive and there are hopes in the future of creating mammoth embryos in artificial wombs before implanting into surrogate female elephants.

10 COOL THINGS WE LEARNED THIS MONTH

1 The UK will host commercial space flights from 2020

The UK is set to launch its first flights into space. A new Spaceflight Bill has sanctioned a £10 million ($12.4 million) grant to develop the commercial launch capabilities for spaceflight, which will allow Britain to join the booming commercial space age.

2 There's an eighth continent

Zealandia could be the world's eighth continent. Located in the southeast Pacific Ocean, 94 per cent of its five million square kilometres are submerged underneath the water. The remaining six per cent includes islands like New Zealand and New Caledonia, and geologists believe that it should be considered a continent as it is comprised of continental and not oceanic crust. The discovery will help shed more light on the area's geological history.

3 Mars will form a ring from its moons

Astronomers have predicted that in a few million years, Mars may have a band surrounding it not too dissimilar in appearance to Saturn's famous ring. Research has predicted that the impact of meteorite strikes and Mars' gravity will eventually shatter its moons, Phobos and Deimos. The fragments will then join the particles already in Martian orbit to form a band of rock around the Red Planet.

4 Prehistoric reptile gave birth to live young

A fossil of a prehistoric reptile has been discovered in south China with an embryo inside. The dinocephalosaurus was an aquatic creature and it is the first archosauromorpha (today represented by birds and crocodiles) found to show evidence of giving birth to live young. It's predicted that the dinocephalosaurus gave birth in the ocean as its long neck made laying eggs on land difficult. The finding suggests that crocodiles and birds could evolve to give live birth in the future.

5 Hibernation may improve cancer treatment

Research on hibernating animals has suggested that a cooled, deep sleep can protect the body against the toxic effects of radiotherapy. Scientists have taken this idea and speculated that putting a cancer patient into an induced torpor state will allow the body to endure stronger radiotherapy treatment.

6 Vitamin D could help to prevent colds and flu

A recent *British Medical Journal* survey has claimed that 3 million fewer people in the UK would suffer from respiratory infections if Vitamin D supplements were part of their diet. While the evidence is inconclusive, Public Health England recommends that people consider taking a daily Vitamin D supplement in winter.

7 Scientists can alter memories

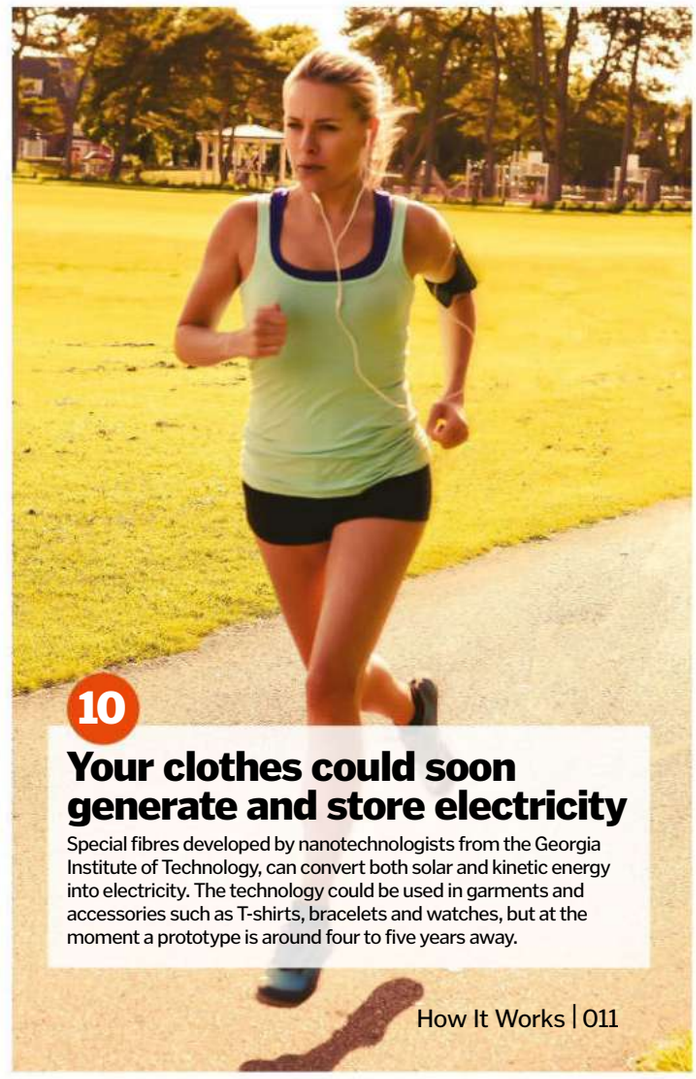
Research has found that as we recall a memory, the connections that formed it can be strengthened and changed. Patients can learn to remain calm when recounting a traumatic memory with the help of a chemical that inhibits the stress response. After several sessions, the connections of the brain will adjust and the chemical will no longer be needed.

8 NASA tech will help guide planes for shorter flights

A joint venture by the Federal Aviation Administration (FAA) and NASA is aiming to make air travel more efficient. The idea is to incorporate automated digital planning software and GPS into air traffic control at airports to replace voice communication and radar. Early tests have proved successful and the changes will help save fuel and allow more flights to arrive on time.

9 VR can help calm anxious children in hospitals

Children can be very nervous during hospital appointments, but VR technology could help. A scheme is being put forward to provide children with a virtual reality helmet to prepare them for MRI scans. Young patients have been invited to go for a virtual snorkel as anaesthetic is administered, and a mobile app is being made available so children can experience what the MRI scan will be like in advance.



10 Your clothes could soon generate and store electricity

Special fibres developed by nanotechnologists from the Georgia Institute of Technology, can convert both solar and kinetic energy into electricity. The technology could be used in garments and accessories such as T-shirts, bracelets and watches, but at the moment a prototype is around four to five years away.

CLIMATE CHANGE MYTHS BUSTED

DISCOVER THE ANSWERS TO 11 OF THE MOST COMMON MISCONCEPTIONS ABOUT CLIMATE CHANGE

Climate change is one of the defining scientific and political challenges of our time. Since 1880, the global average temperature has risen by up to 0.8 degrees Celsius.The ten warmest years ever recorded all occurred within the last two decades. The global sea level has risen by 17 centimetres in the past century. And, in 2013, the amount of carbon dioxide in the atmosphere reached a record high of 400 parts per million. The world is changing, and scientists are concerned.

It's not so much the amount of change that's worrying, it's the speed. In the past 100 years, the rate of temperature increase has almost doubled. That's a warning sign that something isn't right. It's estimated that if we don't change the way we live, carbon dioxide levels could soar to 1,500 parts per million over the next few hundred years. Ice will melt, sea levels will rise, weather and environments will change, and the effects could be felt for millennia.

But we haven't seen the worst of it yet, and that's the problem. Glaciers are starting to retreat, Arctic ice is thinning, and animals are already having to adapt to changes in their environment. But day-to-day life for many hasn't changed and there are still lots of questions that need to be answered.

Scientists are working to monitor the planet and to model the possible effects of changes in our climate. Satellites are pointed at the Earth, taking pictures and making measurements, and scientists on the ground are conducting studies to find out what's happening now, what happened in the past and what might happen in the future.

As this data floods in, governments are trying to take action. Taking advice from experts in the field, they are working to mitigate the risk that climate change poses to the planet. If we act now, we might be able to reverse some of the damage of human-made climate change, but the steps that need to be taken are painful, and acting before we know what's going to happen makes many feel uneasy.

The trouble is, we only have one planet. If we wait to see how the effects of climate change play out, it could be too late.

"THERE'S NO GLOBAL WARMING BECAUSE THE WEATHER'S BEEN COLDER!"

BUSTED

Freezing weather in cities like New York has confused people about global warming

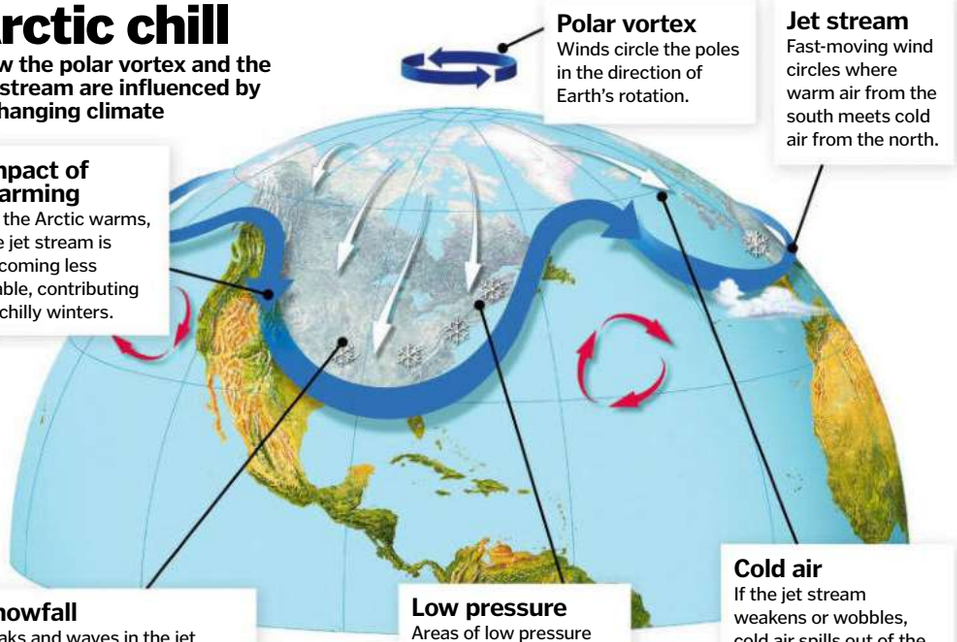
This past winter, temperatures in southern Europe plunged to double figures below freezing, and countries used to mild weather were carpeted in thick snow. Across the pond in the US, the National Oceanic and Atmospheric Association (NOAA) reported double the number of extreme snowstorms in the last half of the 20th century compared to the first. In the face of this Arctic weather, it's no wonder that climate sceptics find global warming hard to believe. But weather isn't the same as climate. Weather is the state of the atmosphere for a short period, climate describes what's happening long-term.

The Arctic is circled by a polar vortex – circular winds that contain the chilly air. At the edges, the vortex interacts with a jet stream that brings warm air up from the equator. Normally, the worst of the winter chill is confined by this air movement, but an increase in air pressure over the Arctic, or a disruption in the jet stream, can send frigid weather southwards.

Overall, global temperatures have been rising and it's about a degree hotter today than it was in 1880. While fluctuations in air movement have been sending cold weather into North America, Europe and Asia, the average temperature has been climbing, hence the widespread concern.

Arctic chill

How the polar vortex and the jet stream are influenced by a changing climate



© NASA; 3D: Thinkstock

This NASA satellite image shows snow blanketing the UK in the winter of 2010

"SCIENTISTS DISAGREE ABOUT CLIMATE CHANGE"

BUSTED

The Earth is getting warmer; temperature records from independent organisations for more than 100 years show that the planet is heating up. The debate comes down to what's causing the rise, and climate scientists are pointing the finger at us.

Searches have been made to pull out published work referencing phrases like 'global climate change' and 'global warming'. These papers have been analysed to find out whether the scientists agree that it is happening, and about the cause. The results of seven of these independent studies were published in 2016, and together they found that between 90 and 100 per cent of publishing climate scientists agree that global warming is caused by humans.

Backing them up are the National Academies of Science from 80 countries across the world, along with the Intergovernmental Panel on Climate Change (IPCC), a hundreds-strong team of climate experts working with the United Nations. It's hard to argue with that. Humans need to face up to their culpability, and fast.

The red parts of this map show areas that were warmer between 2000-2009 compared to 1951-1980

"THE CLIMATE CHANGES WE'RE SEEING TODAY ARE COMPLETELY NATURAL"

BUSTED

Earth has been warmer before. In fact, it's been much warmer. Geological records can reveal the state of the planet in the distant past, and during the Early Eocene Period, 54-48 million years ago, temperatures were up to 14 degrees higher than today. It was so hot that the ice at both poles completely melted.

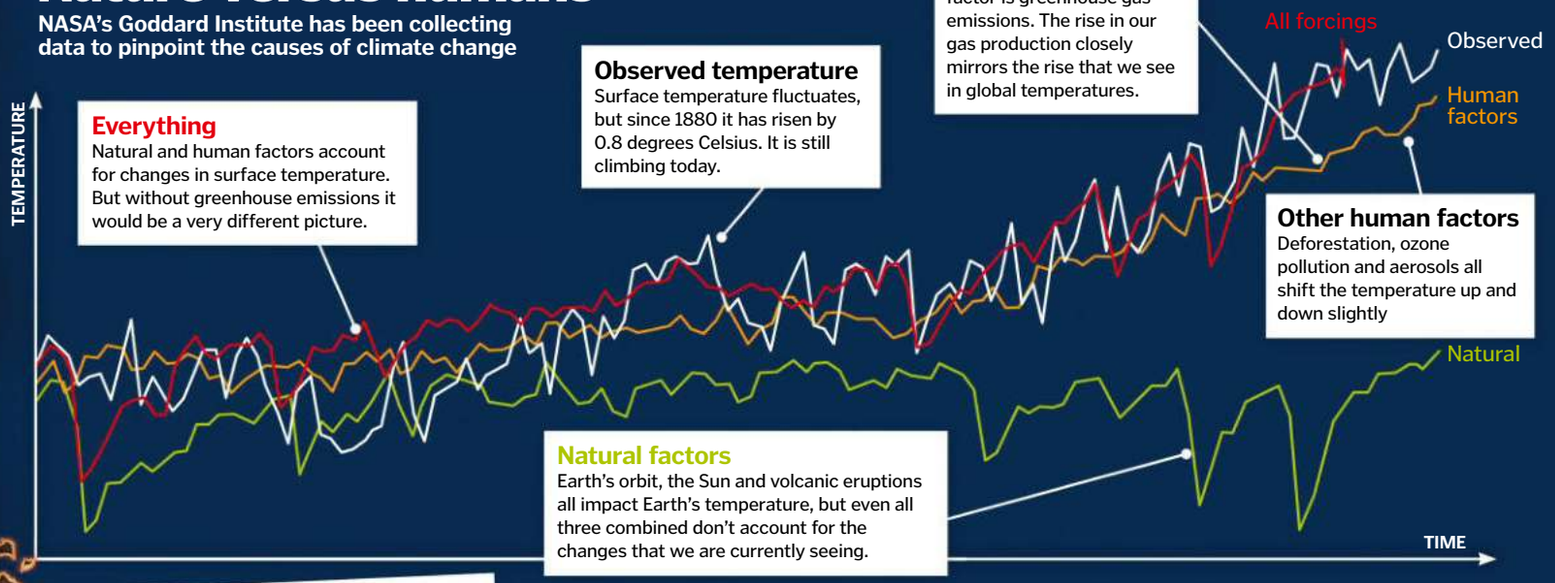
Our orbit around the Sun is uneven, and as we drift closer to or further from our star, this affects our planet's climate and has been linked to the onset of ice ages. The Sun brightens from time to time, kicking out more energy, and volcanic eruptions can fill Earth's atmosphere with carbon dioxide (heating things up) or light-blocking particles (cooling things down). These factors have changed the temperature of the Earth, and will continue to affect it in the future, but that's not what's happening now.

Over the past few decades, temperatures have been rising fast. Sophisticated models of global temperature, ignoring any human input, can recreate the patterns we've observed up until the 1950s, but after that point they can't account for what's going on. Factor in the effects of the emissions humans are creating, and suddenly the models fit.

Human activity is enhancing the natural warming of the planet. We're flooding our atmosphere with carbon dioxide and methane, and it's acting as a blanket

Nature versus humans

NASA's Goddard Institute has been collecting data to pinpoint the causes of climate change



Everything
Natural and human factors account for changes in surface temperature. But without greenhouse emissions it would be a very different picture.

Observed temperature
Surface temperature fluctuates, but since 1880 it has risen by 0.8 degrees Celsius. It is still climbing today.

Human factors
The largest single human factor is greenhouse gas emissions. The rise in our gas production closely mirrors the rise that we see in global temperatures.

Other human factors
Deforestation, ozone pollution and aerosols all shift the temperature up and down slightly

Natural factors
Earth's orbit, the Sun and volcanic eruptions all impact Earth's temperature, but even all three combined don't account for the changes that we are currently seeing.

Rising temperatures increase the risk of extreme weather

"EXTREME WEATHER IS DIRECTLY CAUSED BY CLIMATE CHANGE"

BUSTED

There have been many more cases of extreme weather hitting the headlines over the past few years. Take the US for example, where heat waves are increasing in frequency, even in chilly states like Alaska. Winter storms are becoming more frequent and more intense and the proportion of rainfall happening in single-day flash events is increasing. Storms in the North Atlantic Ocean have also increased in intensity, frequency and duration. But it's hard to link these directly to climate change.

In 2014, NOAA published a report looking at 16 extreme weather events across the world. They found a link between human activity and heat waves, but couldn't prove that the droughts, heavy rain or storms studied were influenced by people. An increasing global temperature does increase the risk of extreme weather, and we can expect events like these to be more common in the future, but it's not yet possible to point the finger at climate change when a big storm hits.

"CO2 ISN'T THE PROBLEM, IT'S METHANE"

BUSTED

When it comes to greenhouse gases, carbon dioxide attracts the most attention. CO_2 levels in the atmosphere have been rising since the industrial revolution, but it's not the only gas responsible for global warming. Methane is 30-times better at trapping heat.

This little molecule is released when organic materials break down. It enters the atmosphere during the production and transport of fossil fuels; it leaks out as the remains of plants and animals decay; and livestock like pigs and cows release it on a daily basis. But it's not the main reason for global warming.

There's far more CO_2 in the atmosphere, and far more of it is being produced. In the US in 2014, it made up 81 per cent of the greenhouse gas emissions, while methane accounted for just 11 per cent. It also hangs around for hundreds, or even thousands of years, unlike methane.

"Scientific evidence for warming of the climate system is unequivocal"
Intergovernmental Panel on Climate Change

"MORE CO2 IS A G THING BECAUSE PLANTS NEED IT"

BUSTED

Carbon dioxide is a key ingredient of photosynthesis. Plants combine it with water under the power of the sunlight to create sugars, which, in turn, indirectly provide energy for pretty much every living thing on the planet. Without carbon dioxide, we wouldn't be here.

Adding more carbon dioxide to the atmosphere does boost plant growth, but in the context of climate change it's not that simple. Stanford University performed a three-year experiment to test what would happen to plant life 100 years from now if our planet keeps changing as predicted.

They doubled the carbon dioxide, raised the temperature by one degree, increased rainfall and increased soil nitrogen (an effect of fossil fuel burning). Under these combined conditions, plant growth stalled.

CO_2 boosts plant growth, but combined with other changes, the effect is reversed

"ANIMALS CAN ADAPT TO CLIMATE CHANGE"

BUSTED

Since life first emerged, Earth's temperature has fluctuated wildly. In the Eocene, it was around 14 degrees Celsius warmer than today, and during the last ice age, it was over four degrees colder.

Species can change their habits, move their homes or even evolve to escape climate change. For example, two-spot ladybirds can be either black with red spots, or red with black. Numbers used to be about equal, but now most are red as it seems to help keep them cool. Pink salmon are spawning earlier in warmer waters, and the quino checkerspot butterfly is moving to higher altitudes.

But these kinds of quick fixes aren't possible for every species. Climate change is happening fast, and evolution is notoriously slow. Many species are struggling to adapt to their changing world.

The extinction of the golden toad has been associated with climate change

"CLIMATE CHANGE IS A CONSPIRACY!"

BUSTED

This myth is the hardest to counter. Many people are automatically sceptical of any evidence climate experts might present.

Climate change isn't just about science – it's also about politics. Changing the way the world works is going to be hard, and it's no wonder that the research is meeting resistance, not least because researchers are still teasing apart the science. Our understanding is building and changing year by year.

But the truth is that internationally respected organisations like the IPCC, NASA, NOAA and the National Academies of Science from over 80 countries agree climate change is happening. The scientific consensus is that human activity is likely to be the cause. When the link between smoking and lung cancer was made, tobacco companies fought to discredit it. Now fossil fuels are in the firing line.

Policies designed to protect the climate have hit businesses hard

Polar bears need sea ice to survive. Without it they face extinction

BUSTED

"A FEW DEGREES WON'T MAKE ANY DIFFERENCE"

Since the late 1800s, the world has warmed by less than one degree Celsius. Sounds small, doesn't it? But a few degrees can make all the difference. Earth's story is written in its rocks, and we know that if the average temperature is just a few degrees colder we're plunged into an ice age. A few degrees warmer and the ice caps start to melt.

Global warming focuses on the global average temperature. In reality, the rise isn't spread evenly across the globe. The International Panel on Climate Change predicted that by 2100, temperatures could rise by as much as 4.5 degrees Celsius, and in some places that spike will be much, much bigger.

In an attempt to slow the warming, the Paris Agreement was signed by 196 countries in 2015. The aim is to keep temperatures below two degrees Celsius warmer than pre-industrial levels, and hopefully to limit it to 1.5 degrees Celsius. That 0.5 of a degree might sound trivial, but it could turn out to be crucial.

The European Geosciences Union, an international union of professional Earth, planetary and space scientists, published a study in 2016 looking at the difference that half a degree could make.

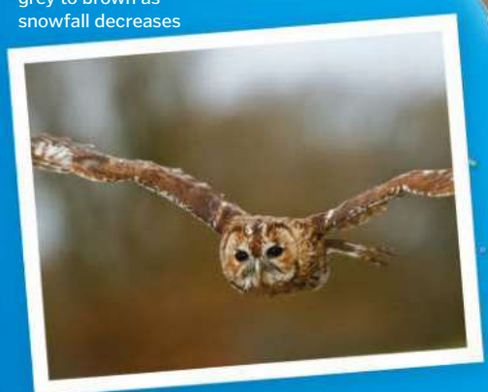
An increase in carbon dioxide levels and temperature is expected to boost the growth of some crops, like soybeans and wheat, but once the temperature tips over the 1.5-degree threshold, this boost could be lost. In some places, temperatures could soar by ten degrees, and extreme heat and drought could cause these vital food crops to fail.

Work to unpick the consequences of the rise in temperature is still in its infancy, but using the available data, scientists in Oxford, UK have also been looking at the difference between 1.5 and 2.0 degrees. This little jump carries an increased risk of extreme weather events, like droughts, floods and storms, which could have devastating effects on populations, economies and of course the environment. Then there's sea levels. It takes a while for the oceans to catch up with the rise in atmospheric temperature, so the full impact of melting ice has yet to be seen. A couple of degrees might sound like nothing, but its impact could be huge.

Desertification
Deserts could spread across large areas of land, with many regions becoming too hot and dry for people to survive.

Amazon desert
Decreasing rainfall across the Amazon could lead to large-scale loss of forest.

Tawny owls are changing colour from grey to brown as snowfall decreases



Vanishing ecosystems
The pristine ecosystem of Antarctica could be completely changed, revealing the land underneath.


"A couple of degrees might sound like nothing, but the impact it could have is huge"
Receding ice
The frozen lands of Siberia and Canada could become warm and habitable.
Habitable zone
The northern hemisphere is likely to have the mildest climate, allowing crops to grow.
Relocation
Unpredictable weather, scorching heat and changes in humidity would lead to mass migration toward habitable regions.
Crop failure
A three-degree rise in temperature would be enough to see crops starting to fail, with major impacts felt in Africa, Central America and South Asia.
Homes underwater
Rising sea levels could engulf islands and coastal towns, forcing residents to flee.
Rising disease
Diseases like malaria could affect thousands more people as the mosquitoes that carry them spread.
Extreme weather
Dry areas could become drier, and droughts and storms could make currently habitable areas completely inhospitable.
Is this our future?
A few degrees rise in average temperature could completely change our world
KEY:
Food growing zones / Compact high-rise cities
Uninhabitable desert
Uninhabitable due to flooding, drought or extreme weather
Potential for reforestation
Land lost due to rising sea levels
©Thinkstock

"THERE'S NOTHING WE CAN DO TO STOP CLIMATE CHANGE"

BUSTED

It's too early to admit defeat. We've spotted our influence on climate change early, and there's still time to intervene. The simplest way to reduce temperature-changing greenhouse emissions is to stop creating them. In 2010, a quarter come from producing electricity and heat, another quarter from agriculture and land use, around 20 per cent from industry, and 14 per cent from transport.

The gold standard is transitioning to renewable energy, and this is already starting to happen. In 2015, carbon dioxide emissions in the UK dropped by 4.3 per cent thanks to a continuing drop in coal consumption. And between 2005 and 2012, emissions in the US dropped by nearly ten per cent.

However, with carbon dioxide levels in the atmosphere having already risen, it would take centuries for things to return to normal even if we do manage to halt our damaging activities. If we want to mitigate the greenhouse effect and halt the rise in global temperature, we need to explore other options too.

One idea is to reflect some of the sunlight back into space by seeding bright clouds over the oceans, or spraying reflective particles into the air. Another is to remove carbon dioxide from the atmosphere, either naturally by planting more trees and encouraging the growth of algae in the sea, or artificially by developing carbon sinks that can suck the gas out and store it.

Switching to renewable energy sources is our best chance at reducing or reversing some of the damage done to our climate

BUSTED

"CLIMATE CHANGE IS CAUSED BY THE SUN"

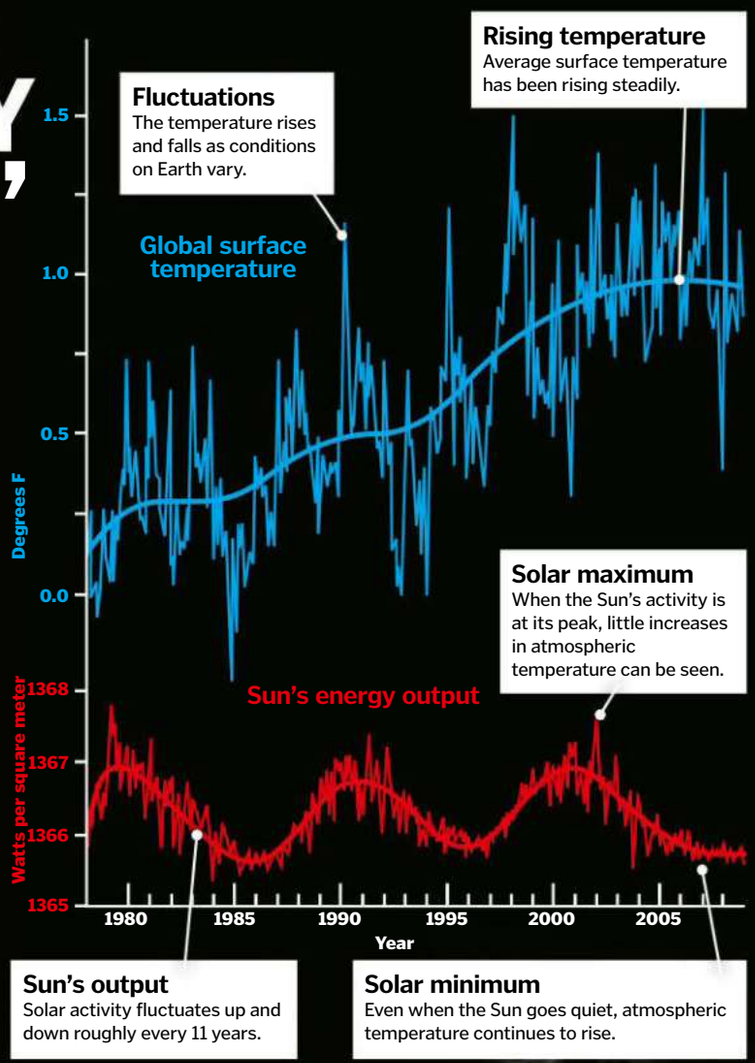
The Sun doesn't put out a constant stream of power. It goes through cycles of increased activity every 11 years or so, culminating in intense sunspots that rage on the surface thanks to fluctuations in its magnetic field. Over the last century, this activity has been intensifying and the Sun is brighter now than it was thousands of years ago. On top of this, Earth's orbit changes shape over time and our planet tips on its axis, changing the length and intensity of the seasons.

In the past, these cycles and changes were linked to fluctuations in temperature on Earth, including the coming and going of ice ages. But warming trends over the past few decades no longer match up to solar activity. As global temperatures have been rising, the Sun's activity has remained stable. In fact, there was a deep solar minimum between 2007 and 2009, but temperatures on Earth continued to rise.

This image shows the active regions of the Sun in April 2015

Is the Sun to blame?

Global temperature versus the amount of energy that the atmosphere receives from the Sun



REVERSING THE DAMAGE

Research is underway to find ways to cool the planet

"As global temperatures have been rising, the Sun's activity has remained stable"

Cloud brightening
Encouraging stable cloud formation over the oceans using fine droplets of seawater could help to reflect the light.

Reflective aerosols
Fine mists of bright particles in the air reflect sunlight back into space, but we don't yet know how best to use them.

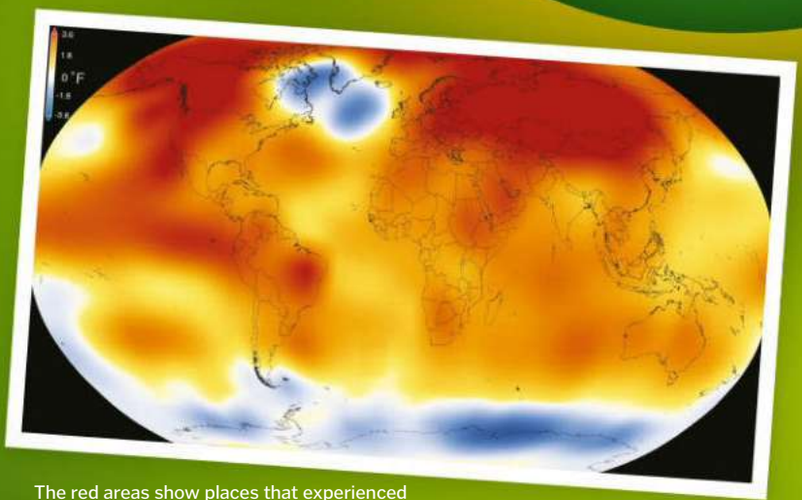
Space mirrors
An emergency plan suggests launching a cloud of transparent mirrors to shield Earth from the Sun in a crisis.

Cycling cold water
Upwelling brings cold, nutrient-rich water to the surface of oceans, feeding algae that trap carbon dioxide.

Fertilising the oceans
Algae need iron to photosynthesise, so adding it to the oceans to boost their numbers is one option being trialled.

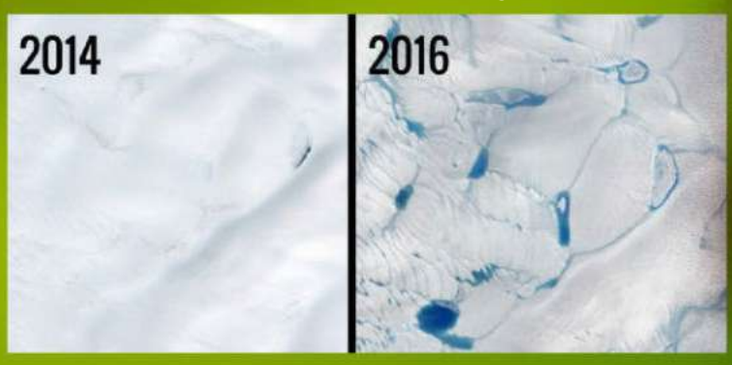
Carbon dioxide capture
Projects are underway to find methods to capture and store carbon dioxide, removing it from the air.

Planting trees
Trees suck carbon dioxide from the atmosphere, so replacing those that we cut down could help slow climate change.



The red areas show places that experienced unusually high temperatures in 2015

NASA's images of the Greenland Ice Sheet show it melting earlier than usual in 2016



Woodpeckers

Discover how these boisterous birds are built to eat, make nests and communicate by whacking on wood

Woodpeckers are a very successful animal family. Over 180 species of these distinctive birds are found worldwide, and they appear on every continent except Australia and Antarctica. They are adapted to many different habitats – you can spot woodpeckers in tropical rainforests and woodlands, but also in grasslands and bamboo forests.

Best known for hammering trees, woodpeckers' three-layered beaks are built for heavy-duty use. The outer layer is made of keratin scales, the same substance that makes up rhino horns. The middle layer is made up of porous bone, and the inner layer of bone with collagen fibres. Together, this construction minimises mechanical stress, which is a good thing, since the average woodpecker will smack its beak against something a staggering 12,000 times per day! These birds lead a busy, noisy life.

There are multiple reasons that woodpeckers loudly thwack things with their beaks. In addition to searching for food, they also create nest cavities and communicate with each other by rapping on objects in specific rhythms.

They wield their beaks like a chisel or a drill. They will crowbar back pieces of bark to grab bugs hiding behind, but also bore directly into trees to reach larvae and insects. A woodpecker will grab prey with the tip of its probing tongue, with some species featuring barbs on their tongues to help secure more food.

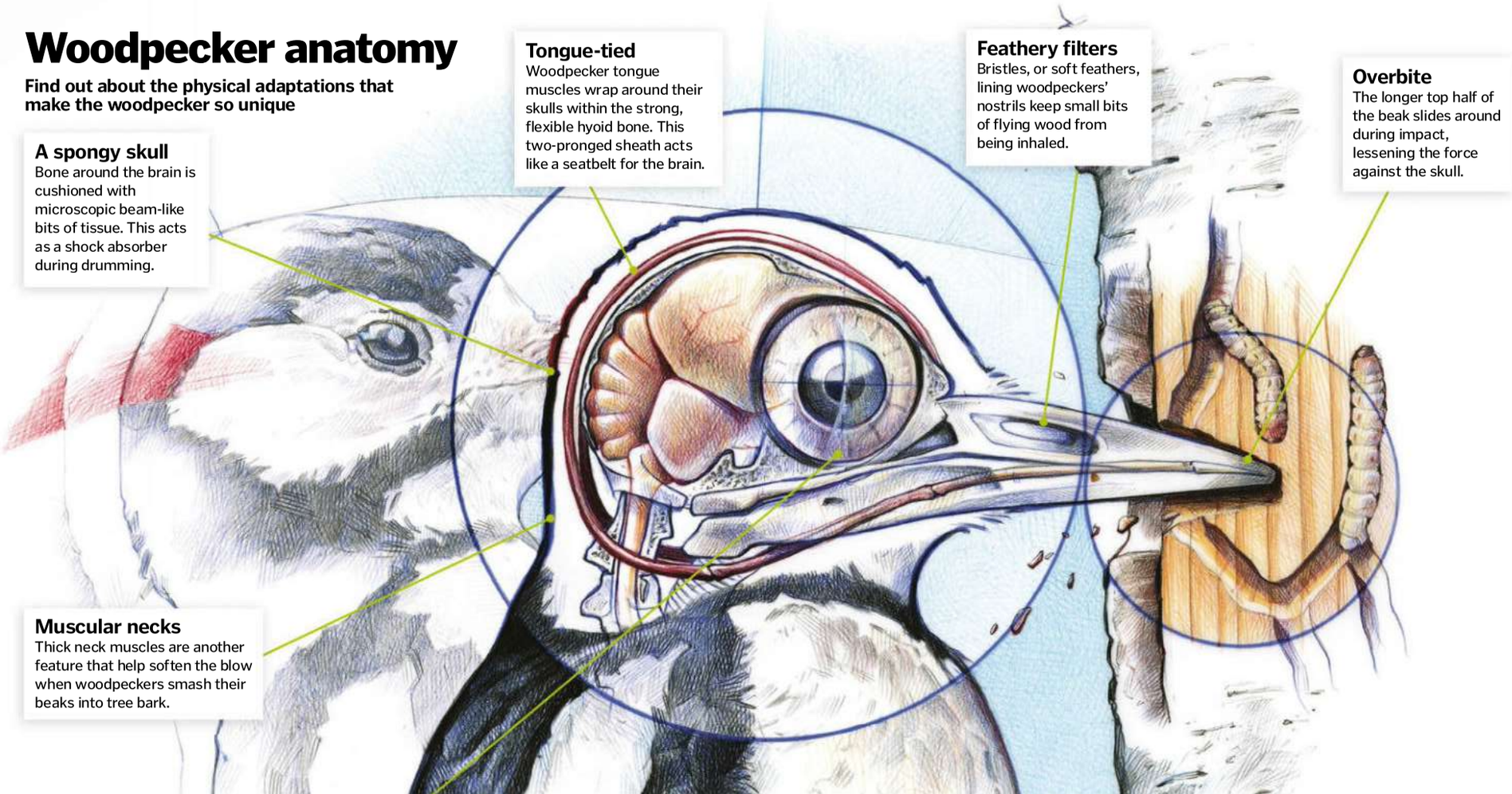
Some feed specifically on cactus fruits. Others amble along the ground licking up ants. Still others store away whole caches of acorns by hammering them into oak trees one nut at a time. But most woodpeckers are willing to eat a variety of food. They feast on caterpillars, spiders, fruit, tree sap, lizards and even other birds' eggs.

Both males and females hollow out tree cavities to rear young. Once the blind and featherless babies hatch, the parents alternate bringing food to the nest or guarding it until the young leave home, typically after 25-30 days.

Since they don't sing, woodpeckers will perform a type of pecking called drumming to warn about predators, mark territory against a rival or attract a mate. They'll often peck artificial objects to create a deeply resonant sound, which means you may find woodpecker holes in utility poles, and dents in bins, rain gutters or the siding on houses.

Woodpecker anatomy

Find out about the physical adaptations that make the woodpecker so unique



A spongy skull
Bone around the brain is cushioned with microscopic beam-like bits of tissue. This acts as a shock absorber during drumming.

Tongue-tied
Woodpecker tongue muscles wrap around their skulls within the strong, flexible hyoid bone. This two-pronged sheath acts like a seatbelt for the brain.

Feathery filters
Bristles, or soft feathers, lining woodpeckers' nostrils keep small bits of flying wood from being inhaled.

Overbite
The longer top half of the beak slides around during impact, lessening the force against the skull.

Muscular necks
Thick neck muscles are another feature that help soften the blow when woodpeckers smash their beaks into tree bark.

Safety goggles
A clear third eyelid keeps woodpeckers' eyes from popping out while they're working. It also protects against errant woodchips.

Getting a grip
Feet with two toes in each direction enable woodpeckers to cling on to the side of trees for long periods of time.

"Woodpecker's beaks are partly made of keratin, like rhino horns"

Partners in crime

Some woodpeckers have teamed up with fungi to create tree cavities faster. Researchers have discovered that red-cockaded woodpeckers appear to carry spores of fungi around with them. These spores grow inside the pine tree cavities already created by the birds and help to rot the wood.

Both the birds and the fungi, which is a kind of decomposer, benefit from the relationship. The birds don't have to work as hard to remove rotten wood and the fungi are placed in a space with perfect conditions for them to grow and spread. This arrangement helps other creatures too. Once the woodpeckers move out, other species have a ready-made home.

Fungi flown in by red-cockaded woodpeckers helps the birds hollow out tree cavities to raise their young

Tail support
Stiff tail feathers anchor woodpeckers to trees, supporting their weight. They also provide leverage for pecking strikes.

Avoiding head injuries

You'd think woodpeckers would sustain multiple concussions with their persistent pecking. Fortunately, their bodies are built to withstand this substantial abuse. Being small helps woodpeckers handle the G-forces associated with sudden stops much better than the bigger brains of other animals.

Our brains are like the yellow yolk inside an egg. When our egg heads come to a quick halt, our brains smack into the outer shell. However, woodpecker brains almost directly touch the inside of their skull. This means the brain doesn't slosh around and bump against the skull during impact. Their skull is also made of thick, spongy bone.

This construction is a kind of shock absorber, like having a helmet on while you're riding your bicycle. Another advantage is that the bone that houses the tongue, called the hyoid, encircles the skull. It's essentially a seatbelt for the brain. Pretty heady stuff!

A woodpecker's anatomy helps protect its brain from the forces of pecking

How sunrays form

To create these beautiful beams, all that's needed is light, clouds, shadows and dust!

If you've ever looked out at a sunset and seen those intense beams of light radiating from what looks like the Sun sinking behind a cloud, then you've seen crepuscular rays. These rays only form when it's partially cloudy, and they are at their best when the clouds are quite thick and low in the atmosphere, such as cumulus or stratocumulus clouds.

As the light from the Sun falls on the clouds, gaps in the clouds let the light through. Dust particles and water vapour in the air cause the light to scatter, much like how the beam of a torch appears if you shine it through smoke. This is what makes the rays so obvious to the human eye. The shadows cast by the clouds themselves enhance this effect. The 'sunburst' appearance is actually an optical illusion – the rays are in fact parallel. Where the rays appear to burst from a single point is just down to perspective.

Things look smaller the further away they get, like when you are looking down a railway track. The lines seem to converge in the distance but really you know that they always run parallel to each other. The same is true for crepuscular rays.

Less common, but still an atmospheric spectacle, are anticrepuscular rays. These are rays that appear to burst from the point directly opposite the Sun. For example, if you're watching a sunset and you're facing the Sun, the anticrepuscular rays will be behind you. These rays are formed in the exact same way and are just counterparts of crepuscular rays. Think back to the railway tracks analogy – if you're looking in one direction and the tracks seem to come together in the distance, then you turn around and look the other way, the same will appear to be true. This is the same with crepuscular and anticrepuscular rays. See if you can spot them the next time you gaze at a sunset.

Our perspective from the ground makes it look like the rays are beaming out of the Sun. The cloud height and distance enhances this view

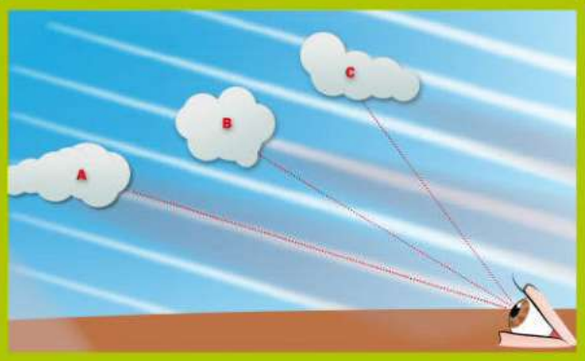
DID YOU KNOW? *Crepuscular means 'of, relating to or resembling twilight', as these rays are most often seen at dawn and dusk*

Light and shadow

How sunlight and clouds work together to form crepuscular rays

Contrast
Rays are most visible during sunrise and sunset as the contrast between light and dark is most obvious at this time.

Particles
Atmospheric particles like dust and water vapour scatter the light to create the 'beams' of light.



The rays are actually near-parallel beams, but as the thick clouds filter the light, we see them very differently from our point of view down here on Earth

"Where the rays appear to burst from a single point is just down to perspective"

Clouds
These Sun rays are most commonly seen when there are thick, low-lying clouds in the sky.

Sun
From this point of view, the rays appear to be radiating from the Sun's position in the sky, but they are actually near-parallel beams of light.

The tropics

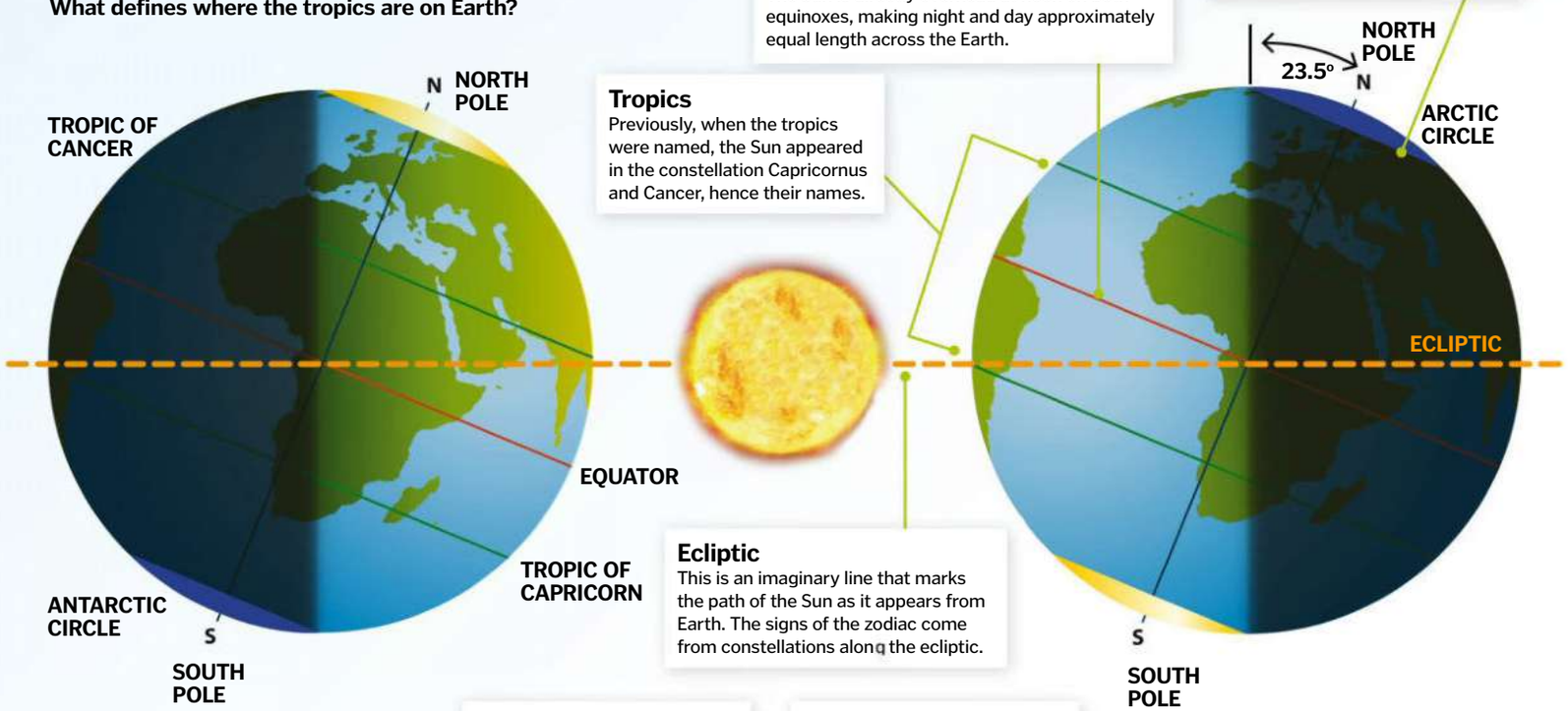
What exactly does the Sun have to do with these parts of the Earth?

The Tropic of Cancer crosses Northern Hemisphere regions such as Mexico, the Bahamas, the Sahara, Saudi Arabia and India, plus others

Imagine two invisible parallel lines that circle the globe at the same distance both above and below the equator – the area within these lines is known as the tropics, or the Torrid Zone. The lines of latitude lie both 23.5 degrees north and south of the equator (known as the Tropics of Cancer and Capricorn respectively). The Sun shines more directly on the tropics than on higher latitudes, and as a result the weather is hot and humid, and tropical storms are frequent.

Cancer and Capricorn

What defines where the tropics are on Earth?



All about blossom

What is blossom and what does it do?

One sure sign that spring is nearly upon us is the appearance of blossom, the name given to the intense clusters of small flowers on trees. It is most often attributed to fruit trees, such as the cherry, apple and peach varieties.

The flowers begin to appear in spring, most famously in Japan, where the sakura (cherry blossom) is celebrated every year by hanging paper lanterns in the trees and enjoying a picnic below the branches. Some species, such as the cherry tree, take their cues for when to blossom from a 'temperature sum' – a prolonged period of constant temperature before the buds emerge.

The vibrant colour and scent of the flowers is an evolutionary adaptation for attracting insects, who play a vital role. Trees need bugs to visit their flowers, pick up pollen and transfer it to other flowers (either on the same tree or from other trees, depending on the plant species) to fertilise the ovary. After fertilisation, the trees can grow fruit, which is the seed-bearing structure formed by the ovary. The blossom petals will then whither and drop from the tree.

A hysteranthous tree is one that blossoms before it opens its leaves

NEXT-GEN MOTORBIKES

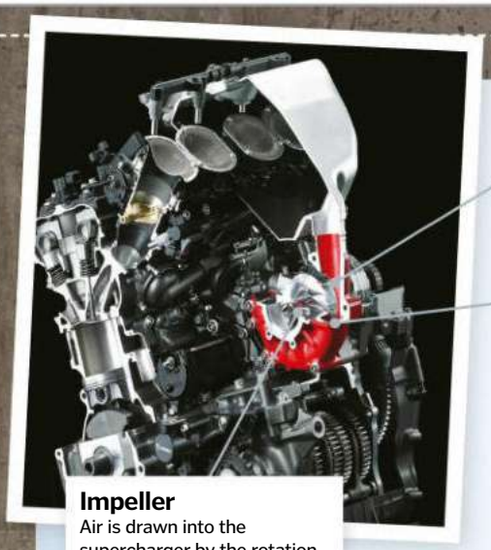
Discover the technology that will make motorcycles the future's most exciting mode of transport

Traditional design principles underlie the Motorrad VISION NEXT 100, BMW's motorbike of the future

If media reports of major technology companies experimenting with self-driving cars have got you thinking that advances in transportation are restricted to vehicles with four wheels, think again. The motorcycle is also heading into a high-tech future every bit as thrilling as that of the car. It makes sense that the same innovations being tested in cars are also on the agenda for motorbike manufacturers. After all, the cool futuristic aesthetics of modern superbikes have given them a prominent place in popular culture, such as the comic book series *Judge Dredd* and the movies *Tron* and *Terminator Salvation*. The image of the modern sport bike is perfectly suited to a notion of a future where our machines are sleek, clean and powerful.

On a more down-to-earth level, motorcycle enthusiasts face many of the same issues that car owners struggle with, such as how to keep down the cost of maintenance and fuel and find safer and more environmentally friendly ways to travel. The impetus for improving motorcycle technologies is driven by both commercial and personal interests.

The first production motorcycle, the Hildebrand & Wolfmüller, was built in 1894. Its engine was rated at almost 1,500cc (cubic centimetres), a measure of the volume of the cylinders. Ostensibly, the bigger the cc, the more power a motorcycle engine can produce. But that's far from the whole story, as evidenced by today's fastest motorbikes. Modern motorbike engines are considered to be big at 1000cc. Yet, the top speed of the latest superbikes doesn't fall far short of 320 kilometres per hour, and the Kawasaki Ninja H2R can reach around 400 kilometres per hour. That's almost ten times as fast as the Hildebrand & Wolfmüller could go. These speeds are the result of advances in



Impeller
Air is drawn into the supercharger by the rotation of this component and then pushed into the engine.

Planetary gears
Kawasaki turned to its aerospace division to design gears able to transfer the supercharger's power.

Centrifugal-type supercharger
This type of supercharger essentially force-feeds air into the engine, boosting internal combustion.

Kawasaki Ninja H2R

If it is power you want from a motorcycle, you'll find plenty of it in this mean machine. Indeed, the Kawasaki Ninja H2R is so powerful, it would be illegal to ride one on the road. The design combines principles of physics with precision engineering. As a bike designed for closed course riding only, it has engine components that are specifically designed to ramp up the horsepower far in excess of what is typical for street-legal production motorcycles. Moreover, it comes with a fairing that looks like the front end of a jet fighter, and for good reason. The pointed nose, cowls and wings are shaped at just the right angles to minimize wind resistance and friction-induced heat build-up. But it's not just the mechanics that are top drawer. State-of-the-art electronics ensure that the ride is smooth, safe and under control, even at 400 kilometres per hour.

Wheels up
Launch Control Mode allows the rider to engage maximum acceleration from a standstill without pulling a wheelie.

Fast and furious

This superbike is the result of clever design and cutting-edge engine technology

Electrical connections
The electronic system includes functions to aid cornering, traction, braking, acceleration, steering and gear shifting.

Hot wheels
The World Superbike Championship-styled wheels are made of lightweight cast aluminium, while the rear tyre measures 200mm for maximum traction.

Tough brakes
To ensure effective breaking at very high speeds, the semi-floating brake discs are extra-large.

998cc engine
The moving parts of the four-cylinder engine are fine-tuned to keep up with the supercharger.

Aerodynamic design
The light-weight fairing was designed by aeronautical engineers to generate downforce, which stabilises the bike at high speeds.

"The Kawasaki Ninja H2R is too powerful to ride on the road"

technology that allow motorbike engines to generate extra power or operate more efficiently.

The Ninja H2R, for example, is fitted with a supercharger that boosts the power output of the engine to levels too high for road use. Along with other superbikes such as BMW's S1000RR and Ducati's 1299 Panigale S, it also includes sophisticated features that control the bike's mechanics on the fly to ensure the best possible ride. These include dynamic traction control, which maintains a consistent grip on the road and thereby provides improved manoeuvrability, braking and acceleration. Essentially, a traction control system constantly monitors whether the wheels are turning at the same speed. If a difference is detected, the power going to the rear wheel can be adjusted to slow it down. One example is Italian firm GripOne's 3D-Intelligence system, which receives data from sensors that measure variables such as tyre load, speed and the bike's lean angle up to 200 times per second.

The next generation of motorbikes could be even more manoeuvrable if flexible smart materials supersede conventional jointed bike frames. This idea is built into BMW 's Motorrad VISION NEXT 100 concept bike, the German auto maker's vision of two-wheeled transport in the 2040s. The bike's so-called Flexframe is one piece that turns in its entirety in response to

Honda Riding Assist

The revolutionary technology that keeps a bike upright even when it's standing still

Self-propelled
Honda has demonstrated the Riding Assist bike starting, stopping and manoeuvring through doors without a rider.

Small turns
Slightly turning the front wheel left and right helps to keep the bike upright.

Shapeshifter
When the bike is standing still, the angle of the front forks changes, extending the wheel outwards.

No gyroscopes
Rather than use traditional gyroscopes, which would add considerable weight, Honda's engineers have used balancing technology from their ASIMO robot.

The Hildebrand & Wolfmüller's four-stroke engine was capable of providing speeds of up to 45km/h

steering. This should reduce mechanical stress and wear on moving parts.

Other features of this bike, according to BMW, are tyres that adapt to the terrain and an engine that changes shape to improve aerodynamics depending on whether the bike is stationary or moving. BMW's prototype is also fitted with a digital companion that makes imperceptible changes to the engine to keep it running in an optimum state for the prevailing conditions.

Although state-of-the-art bikes like the VISION NEXT 100 and Ninja H2R have taken on-board computers to the next level, electronic systems that allow a rider to perform actions like braking and shifting gears with a single button are not new. Many premium motorbikes now include ride-by-wire technology as standard, which replaces the old system of cable connections between the rider's controls and the engine. When the rider opens the throttle, for instance, the action is converted to an electrical signal by a transponder. This signal is then sent to the bike's electronic control unit, which initiates the appropriate follow-up action, such as injecting more fuel.

Wireless technology is also linking riders to their bikes through their clothing. Bluetooth-enabled gloves allow riders to control music and answer phone calls. Meanwhile, smart helmets offer the potential for even more sophisticated interaction. Skully captured the headlines in 2014 with a successful Indiegogo campaign that raised money for the development of a helmet that incorporated a rear-view camera, heads-up display (HUD) and a smartphone link for sourcing turn-by-turn directions and hands-free calls. Unfortunately, it never entered production, but it wasn't the only advanced motorbike helmet in development.

Green machines

It isn't quite the same thing as the steam-powered velocipedes of the 19th century, but using hydrogen and oxygen – the constituents of water – in hydrogen fuel cells to power vehicles could make motorcycles greener.

Fuel cells produce electricity through a chemical reaction that strips electrons from hydrogen atoms. Oxygen may later combine with these electrons and the hydrogen atoms, resulting in the production of water as a waste material. Suzuki demonstrated a motorbike called the Crosscage at the Tokyo Motor Show in 2007 that uses a hydrogen fuel cell to charge a lithium-ion battery. However, as appealing as this sounds for its low environmental impact, the Crosscage remains a prototype.

More promising is the use of electrical batteries that can be charged from the mains or a charging station, like Tesla cars. Manufacturers including Zero, Honda and Harley-Davidson are already testing battery-powered motorbikes.

Advanced motorcycles may one day utilise hydrogen as a fuel

Airbus APWorks Light Rider

Meet the 3D-printed motorbike that is light enough to lift by hand

Lightweight
The Light Rider warrants its name because it only weighs 35kg.

Unbreakable
The frame is made of a corrosion-resistant alumninium alloy called scalmalloy that is supposedly almost as touch as titanium.

Body cavivties
Parts of the frame are hollow so that cables can run through them.

Multilayered
Scalmalloy is made up of thousands of layers of aluminium alloy, each of which is only 60 microns thick.

Zippy
The engine is powerful enough to get the bike from 0 to 45km/h in just three seconds.

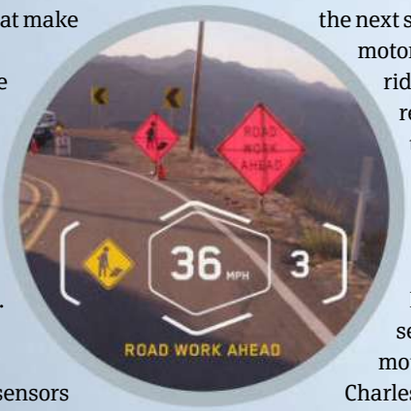
Inspired by life
An algorithm was used to design the body using strong natural skeletal and organic structures as a model.

The Z-Force electric motor found in Zero motorcycles can be charged at standard electrical outlets

"Electric bikes could be charged from a charging station, like Tesla cars"

At CES 2016, BMW displayed a design that also incorporates a programmable HUD. Looking to the future, BMW's engineers are even envisaging a world without helmets. As part of the VISION NEXT 100 project, they've designed data glasses that detect where the rider's looking and accordingly display a virtual rear-view mirror, maps or menus that the rider can manipulate with hand gestures.

Tagged with nicknames such as 'widow makers', motorbikes have long had a reputation for being dangerous. Education about speed and wearing good leathers has gone some way towards correcting that, but manufacturers have also been adding tech that make riding safer. A 2015 report published by the Victoria State Government in Australia concluded that anti-lock braking systems (ABS) could reduce the rate of deaths and severe injuries by 31 per cent. Most road bikes now come with at least the option of ABS.



Like bicycles, motorbikes have separate brakes for their front and rear wheels. Speed sensors monitor how fast these wheels are going. When the rider is applying the brakes, the ABS controller uses this data to make minor adjustments to the brakes on one or both wheels, thus ensuring they don't lock and cause the bike to skid or fall over. Even with ABS, many motorcyclists will fall off their bikes at some point. Thankfully, that's less likely to hurt these days due to recent innovations in what riders wear. UK company D3O has developed special polymers that it uses to make flexible but impact-resistant protective body armour for MotoGP and motocross racers. Several companies are also offering jackets that contain airbags. Alpinestars' Tech-Air jackets, for example, include sensors that activate the internal airbags when the jacket is zipped up. If the rider is thrown from the bike, the airbags rapidly inflate to protect their back, kidney areas, chest and shoulders. But even falling off could become a thing of the past with the arrival of self-balancing motorcycles. Honda is calling its version Riding Assist. The concept draws on the company's work in robotics and physics principles associated with the position of the bike's front wheel. Riding Assist would be a boon to novice riders who struggle with balancing, and all riders will have one less thing to worry about when navigating through slow traffic.

With the recent focus on self-driving cars, the next step after self-balancing motorbikes could be bikes that ride themselves. Google has reportedly already begun testing the idea, and a promotional video for Honda's Riding Assist shows the bike following its rider. Then there are the Brigade and Interceptor self-driving police motorbikes. Designed by Charles Bombardier, founder of Imaginactive.org, it's envisaged that these vehicles could scan for traffic violations and other threats to law and order using 3D cameras. While these designs are only speculative, they foretell a future in which motorcycles aren't going to be geared only to enthusiasts. With vehicles filling up our roads, some motorbike manufacturers are investing in ways to reduce our environmental impact. These include using zero emissions power sources, and vehicles like Toyota's i-Road that blur the lines between cars and motorbikes by borrowing design features from both. These innovations are prototypes today but if they prove to be viable, motorbikes could yet become tomorrow's mode of personal transport for the masses.

"BMW's engineers are envisaging a world where helmets won't be needed"

ABOVE BMW's concept for a heads-up display shows up-to-date journey information on the helmet's visor

RIGHT Toyota's three-wheeled electric i-Road steers like a car but leans around corners like a motorbike

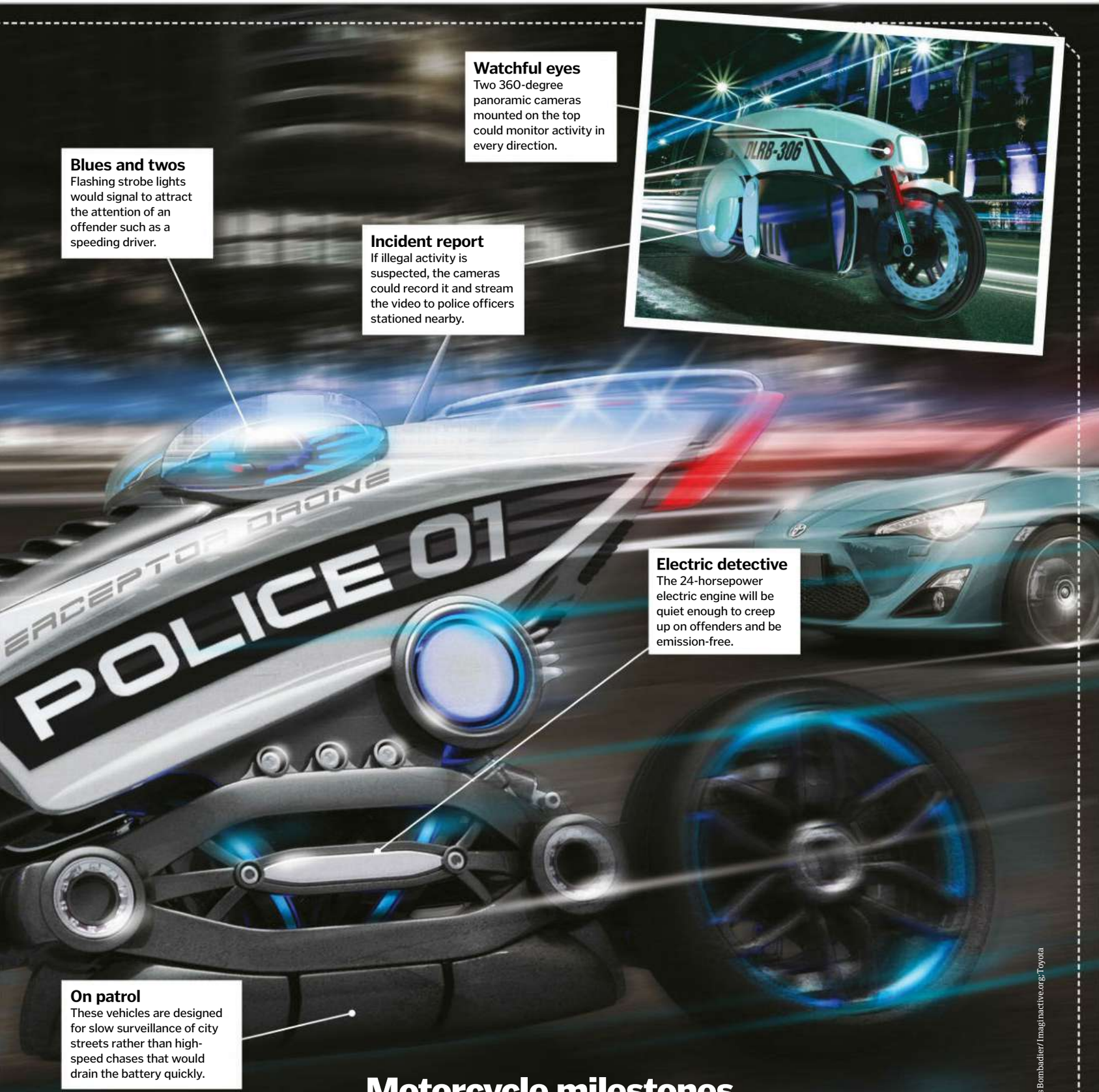
Riderless motorcycles

Meet the two-wheeled patrol vehicle concepts that could replace bobbies on the beat

Body armour
The frame would be built of a high-strength, low-weight material, such as carbon fibre.

Balancing act
Two gyroscope rotors would prevent the bike from falling over when it's motionless or travelling at slow speeds.

Just the ticket
Once an offender is identified from a scanned number plate, they could be sent a ticket by e-mail or SMS.



Watchful eyes
Two 360-degree panoramic cameras mounted on the top could monitor activity in every direction.

Blues and twos
Flashing strobe lights would signal to attract the attention of an offender such as a speeding driver.

Incident report
If illegal activity is suspected, the cameras could record it and stream the video to police officers stationed nearby.

Electric detective
The 24-horsepower electric engine will be quiet enough to creep up on offenders and be emission-free.

On patrol
These vehicles are designed for slow surveillance of city streets rather than high-speed chases that would drain the battery quickly.

Motorcycle milestones

Major events on the route from steam cycles to superbikes

1867
Ernest Michaux builds the Michaux-Perreaux steam velocipede. Several similar inventions soon appear.

1884
Edward Butler unveils the three-wheeled Butler Petrol Cycle, which has a two-stroke engine.

1894
The Hildebrand & Wolfmüller Motorrad (German for 'motorcycle') enters production.

1906
A new Harley-Davidson motorcycle factory is built in Milwaukee, Wisconsin, US.

1949
The first motorcycle Grand Prix takes place on the Isle of Man.

1951
The Birmingham Small Arms Company becomes the world's largest manufacturer of motorcycles.

1970s
Japanese motorcycle companies, such as Suzuki and Honda, start to dominate.

2010
The specially-designed Ack Attack sets the motorcycle world land-speed record at 606km/h in Utah.

Car dashboards

Learn how instrument panels give drivers up-to-the-minute information on what's happening beneath the bonnet

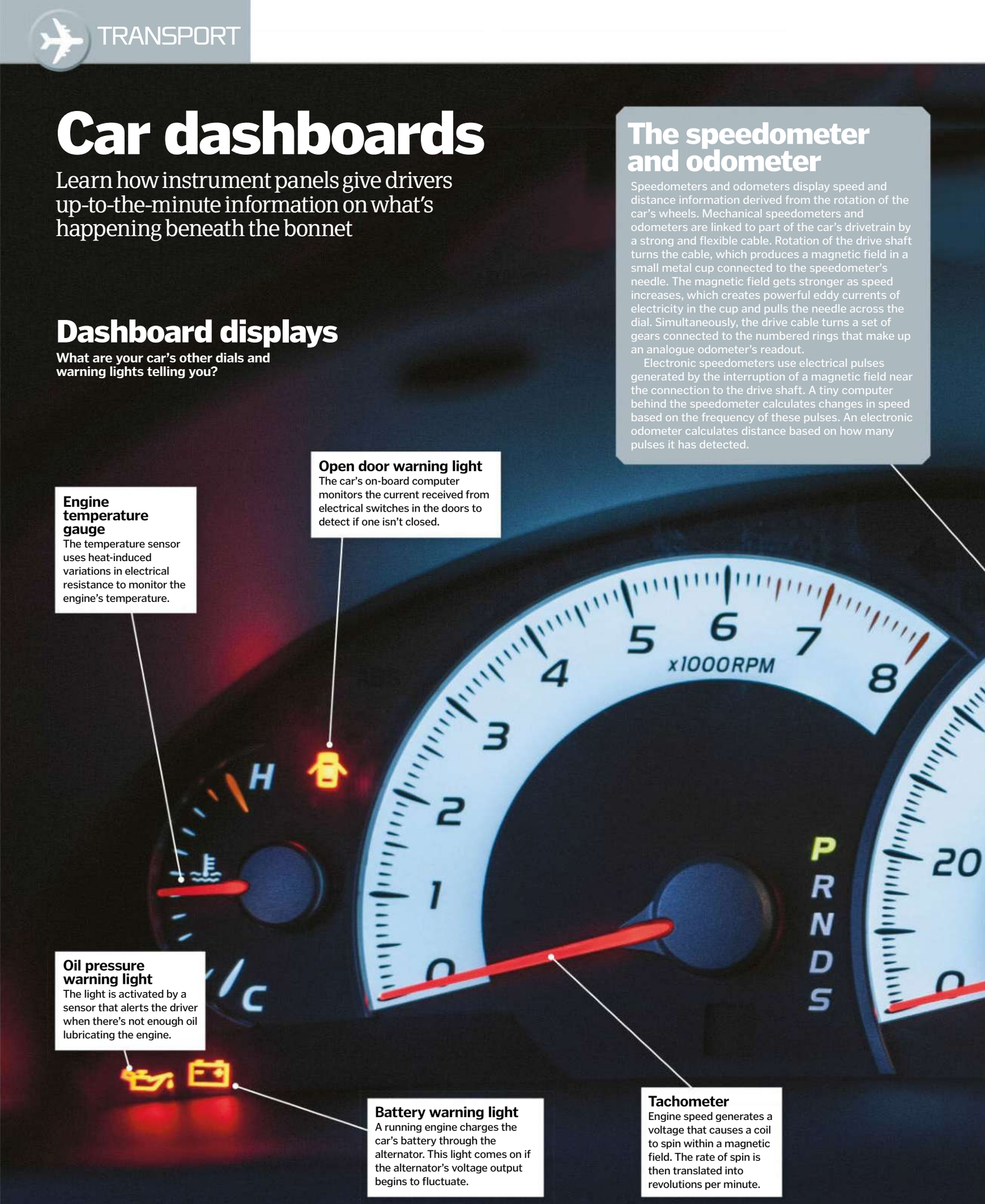
The speedometer and odometer

Speedometers and odometers display speed and distance information derived from the rotation of the car's wheels. Mechanical speedometers and odometers are linked to part of the car's drivetrain by a strong and flexible cable. Rotation of the drive shaft turns the cable, which produces a magnetic field in a small metal cup connected to the speedometer's needle. The magnetic field gets stronger as speed increases, which creates powerful eddy currents of electricity in the cup and pulls the needle across the dial. Simultaneously, the drive cable turns a set of gears connected to the numbered rings that make up an analogue odometer's readout.

Electronic speedometers use electrical pulses generated by the interruption of a magnetic field near the connection to the drive shaft. A tiny computer behind the speedometer calculates changes in speed based on the frequency of these pulses. An electronic odometer calculates distance based on how many pulses it has detected.

Dashboard displays

What are your car's other dials and warning lights telling you?



Engine temperature gauge
The temperature sensor uses heat-induced variations in electrical resistance to monitor the engine's temperature.

Open door warning light
The car's on-board computer monitors the current received from electrical switches in the doors to detect if one isn't closed.

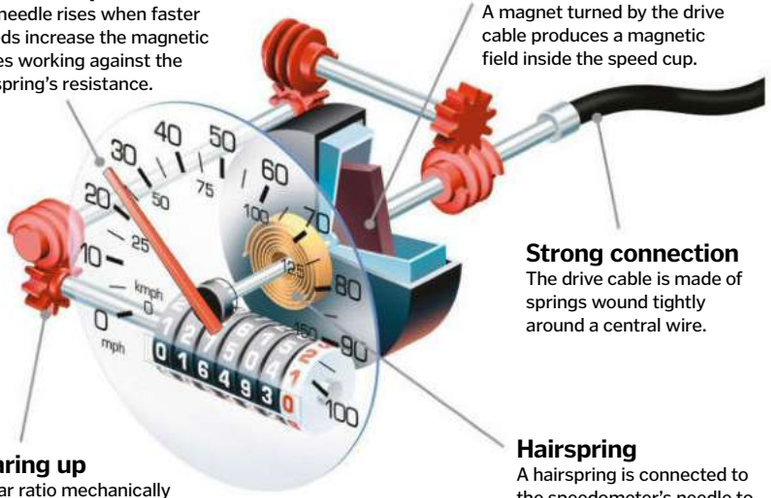
Oil pressure warning light
The light is activated by a sensor that alerts the driver when there's not enough oil lubricating the engine.

Battery warning light
A running engine charges the car's battery through the alternator. This light comes on if the alternator's voltage output begins to fluctuate.

Tachometer
Engine speed generates a voltage that causes a coil to spin within a magnetic field. The rate of spin is then translated into revolutions per minute.

Speed and power
The needle rises when faster speeds increase the magnetic forces working against the hairspring's resistance.

Magnetic attraction
A magnet turned by the drive cable produces a magnetic field inside the speed cup.



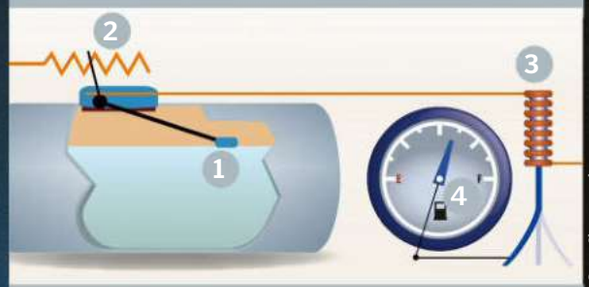
Strong connection
The drive cable is made of springs wound tightly around a central wire.

Gearing up
A gear ratio mechanically conveys the wheels' rotation to the odometer.

Hairspring
A hairspring is connected to the speedometer's needle to constrain its movement.

The fuel gauge

The classic fuel gauge consists of a sending unit in the fuel tank and the gauge itself on the dashboard. Changes in fuel level are indicated by the movement of a float on the surface of the fuel. A rod connects the float to a wiper that moves across a resistor as the float goes up or down with changes in fuel level. When the tank is full, the wiper causes the current to pass a shorter distance through the resister. A stronger current therefore reaches the fuel gauge mechanism. This makes the needle point to a higher position on the gauge. As the fuel level decreases, the wiper directs electricity through more of the resister, sending less current to the gauge and causing the needle to drop. Newer cars use a microprocessor to detect the level of resistance in the circuit and transmit this information to the gauge.

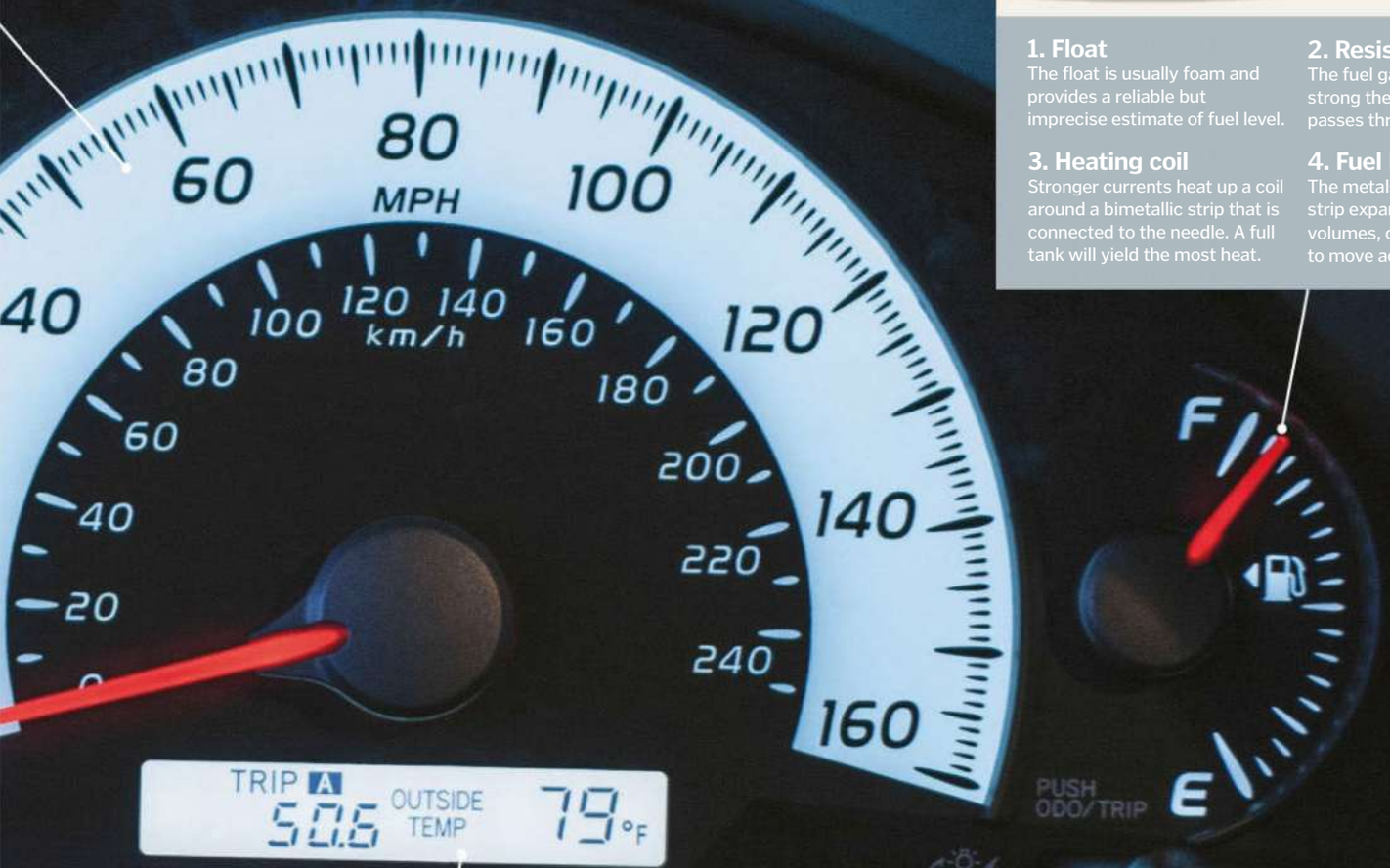


1. Float
The float is usually foam and provides a reliable but imprecise estimate of fuel level.

2. Resistor
The fuel gauge reflects how strong the current is after it passes through the resistor.

3. Heating coil
Stronger currents heat up a coil around a bimetallic strip that is connected to the needle. A full tank will yield the most heat.

4. Fuel level
The metals in the bimetallic strip expand to different volumes, causing the needle to move across the gauge.



Digital display
Digital data, such as trip mileage and outside temperature, are received from on-board computers.

Engine warning light
This light can indicate problems with the exhaust or electrical system or be triggered by various sensors in the engine.

Tandem bikes

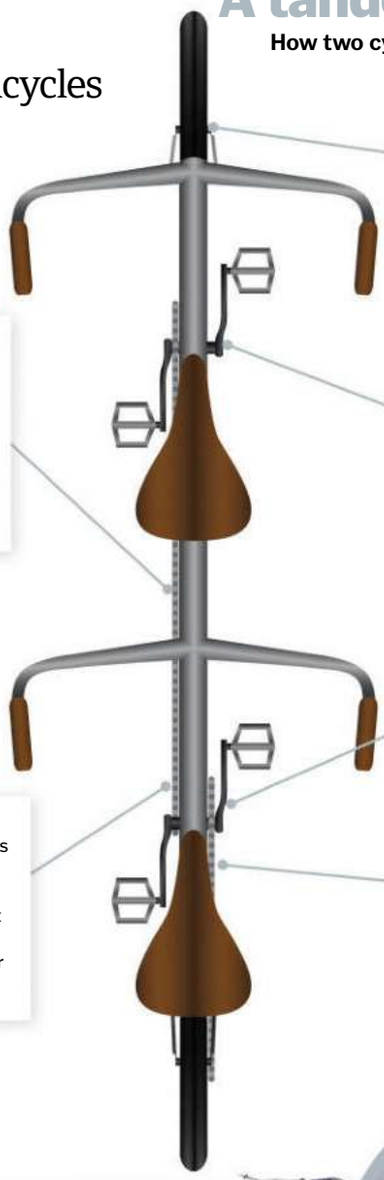
How the drive systems of these two-seater bicycles make them faster than a normal push bike

A typical tandem bicycle has one frame, two wheels and two saddles, although some models have been designed to seat more than two riders. Both riders can pedal but the front rider controls the bike by steering, changing gear and braking. Tandems have long and complex drive mechanisms, with the drive chain turning the wheels and the timing chain keeping the two riders in sync. Crossover drive systems, with the drive and timing systems on either side of the frame, are common, as are single-side, with both chains on the same side.

"Both riders can pedal but the front rider controls the bike"

A tandem's drive train

How two cyclists peddling together in harmony can comfortably ride a tandem bike



Brakes
Tandems have two types of brake. Drum brakes slow the bike down gradually on long descents, while disc breaks can quickly stop the tandem.

Crossover drive system
This tandem has a crossover drive system and is set up with the timing chain on the left and the drive chain situated on the right.

Out of phase
Some tandem riders will purposely set their peddling up out of sync to avoid lag in between pedal strokes.

Crankset
While the front crankset typically has one chainring, the rear crankset usually has many chainrings, often on both sides.

Timing chain
The timing chain keeps the cranks in sync. When 'in phase' both riders have to pedal at the same time. If one needs a rest, the other has to stop.

Drive chain
Drive chains on tandems wear out quickly as they have to contend with the impact of two people cycling rather than one.

The T-50 fighter jet

Russia's new stealth aircraft can avoid radar detection while cruising at supersonic speeds

The Sukhoi T-50 is a Russian twin-engined, fifth-generation fighter that boasts some serious tech. Built to rival the US F-22 Raptor, F-35 Lightning II and the Chinese J-20, it will replace the long-standing MiG-29, which has been in active service since 1981.

Its engines are so powerful that it will be able to cruise at supersonic speeds without the need for an afterburner. Its thrust vector jets allow the pilot to perform tight turns and manoeuvres. The T-50's outer surface is made using carbon fibre composites and the engine is much quieter and energy-efficient than those on rival fighter jets.

The T-50 is a combat machine that packs a punch. Its internally mounted cannon is one of the lightest in its class, but can fire incendiary, fragmentation or armour-piercing rounds to destroy armoured vehicles and other armoured targets. It is also the first Russian fighter to incorporate stealth technology and can remain cloaked to evade enemy radar. The plane will go into mass production in late 2017 and is expected to be introduced into the Russian military the following year.

How jetboards work

Is this the future of surfing? Adrenaline junkies rejoice, the jet-powered surfboard is making waves

Is there anything more annoying than grabbing your board and wetsuit on a beautiful day and heading to the coast, just to arrive and see a flat, calm ocean? Instead of cursing yourself for not checking the surf report, check out the motorised variety of surfing craft.

The WaveJet is a modular 'pod' designed to fit onto almost any surfboard, kayak or stand-up paddle board. It's battery-powered, rechargeable and operated by an accompanying watch unit. Allowing surfers to travel at around three-times faster than paddling, the WaveJet technology works much like the way a jet ski does, just downsized. Twin motors power two miniature water jets that suck in water and then expel it, creating enough thrust to get the rider into the line-up and ready to ride.

A similar competitor is the JetSurf, which is an entire board unit (instead of WaveJet's pod concept) that is designed to be much faster, reaching speeds of up to 58 kilometres per hour. Made of carbon fibre, the JetSurf boards are very light and portable, with bindings to keep the rider's feet on the board. Initially designed for racing on flat water, the JetBoards can also hold their own in the big ocean swell. The 'hull' is hydrodynamically designed and looks almost like a small speedboat instead of a surfboard.

All of this is powered by a small combustion engine with a unique exhaust system that is the key to producing such high speeds that most (sensible) riders have taken to wearing motocross helmets while on the water.

The JetSurf board

The board that gives your surfing skills an extra boost, with no paddling required

Control
Surfers use their body weight to steer, but a hand control attached to the front of the board controls the engine's throttle.

Safety
The hand control also acts as a kill-cord, shutting of the engine if the surfer falls off the board.

Materials
The board is made from carbon fibre, making it light yet strong.

Speedy surf
The Jetsurf can reach speeds of up to 58km/h and could cross the English Channel in less than 45 minutes.

Engine
The Jetsurf is powered by a 100cc engine attached to the back of the board.

History of motorised surfboards

The idea has been floating around since the 1930s, when a few intrepid individuals tinkered with putting motors on surfboards. There are even a few examples of them being used by lifeguards. But it wasn't until the 1960s that the tech took a real step forward. While a few manufacturers put outboard motors on surfboards, the first jetboard wasn't produced until 1965. Designed by aircraft engineers, it was created to get the surfer through the waves to save energy on paddling.

The 1980s saw the invention of the PowerSki JetBoard, where the jet technology was perfected so that the board was faster and more manoeuvrable. A range of boards were developed that could function more like a jet ski – designed for use both on flat water and to catch waves. They were also made from lighter and more manageable materials, paving the way for motorised surfboards today.

MIND TRICKS

Discover the mind-bending illusions that prove you shouldn't always believe what you see or feel

As you go about your daily life, your brain continuously perceives the world around you with the help of your senses. The constant stream of information it receives is overwhelming, so it regularly takes shortcuts to simplify what you see or feel and chooses the most likely interpretations. This helps it to concentrate on what's important, rather than focusing on everything at once. The brain is also very good at predicting the future, helping it to compensate for the slight delay between you physically seeing or touching something and receiving and processing those signals from your eyes or limbs. However, these shortcuts and predictions also make it possible for your brain to be fooled.

Humans have been discovering ways to trick the mind for millennia, with examples of optical illusions found in Stone Age cave paintings. Ancient Greek philosopher Aristotle noted that "our senses can be trusted but they can be easily fooled" with an illusion now referred to as the waterfall effect. While watching a waterfall he noticed that shifting his gaze from the moving water to the static rocks made the rocks appear to move in the opposite direction to the flow of water. Now known as 'motion aftereffect', it's caused by the wearing out of certain neurons in the brain as they perceive motion. When you move to look at the rocks, competing neurons overcompensate for those that are worn out, creating the illusion of movement.

Studying how the brain reacts to illusions has become much easier since Aristotle's day. Functional magnetic resonance imaging (fMRI) allows scientists to analyse the processes going on inside our heads as we experience certain images or situations, examining how the brain responds in real time. However, there is still a great deal more to be explored, as our responses to some illusions remain a mystery.

How we see

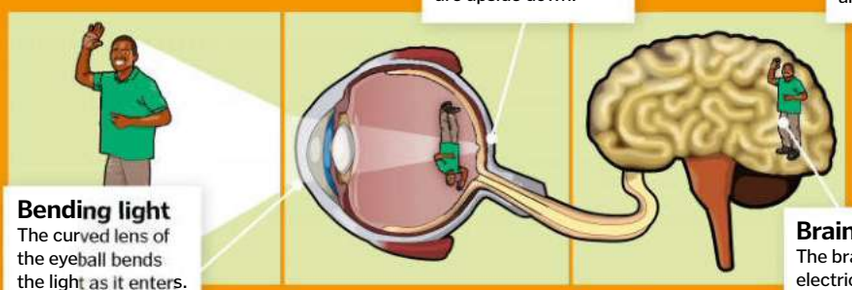
Your eyeballs are your window to the world, enabling your brain to create colourful three-dimensional moving images of your surroundings in amazing detail. They work a bit like a camera, allowing light to enter through a lens, which then focuses it onto a kind of sensor called the retina. Your eyes can even zoom like a camera, as muscles help to flatten the lens to see distant objects, or thicken it to see things close-up.

Once the light hits the retina, it is detected by light-sensitive cells called rods and cones. Rods are responsible for our sight in dark conditions, allowing us to see in monochrome, while cones allow us to see colour and detail in brighter conditions. When the light hits them, chemicals in the rods and cones change, creating an electrical signal that is sent to the brain.

Here the information from each eye is combined and compared so that an image of your surroundings can be accurately reconstructed with plenty of depth and contrast. This whole process takes about a hundredth of a second, enabling you to see the world almost in real time.

The human eye

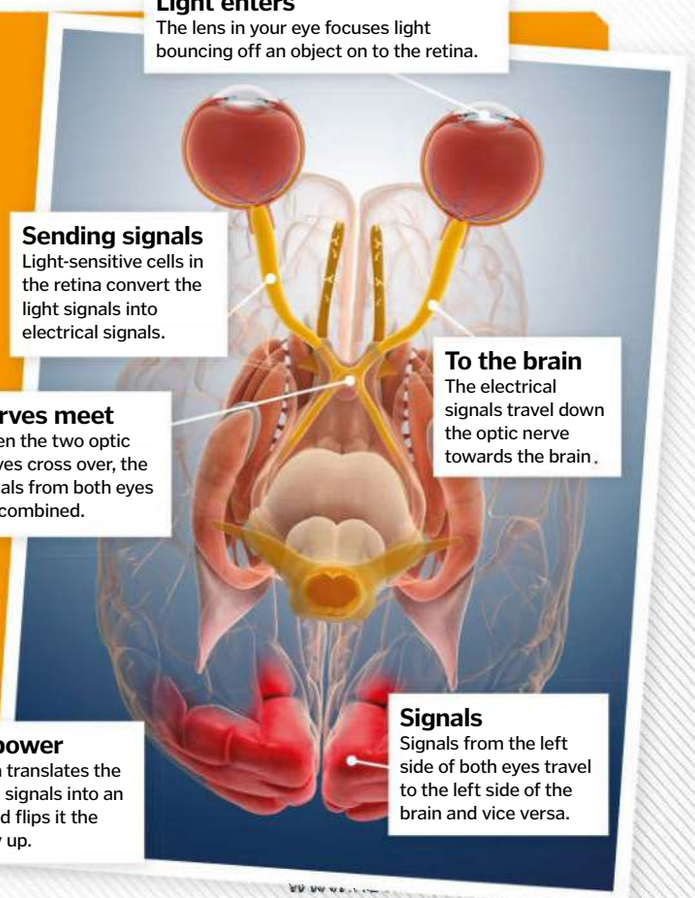
How do we turn waves of light into images of our surroundings?



Bending light
The curved lens of the eyeball bends the light as it enters.

Wrong way up
The light signals received by the retina are upside down.

Brain power
The brain translates the electrical signals into an image and flips it the right way up.



Light enters
The lens in your eye focuses light bouncing off an object on to the retina.

Sending signals
Light-sensitive cells in the retina convert the light signals into electrical signals.

Nerves meet
When the two optic nerves cross over, the signals from both eyes are combined.

To the brain
The electrical signals travel down the optic nerve towards the brain.

Signals
Signals from the left side of both eyes travel to the left side of the brain and vice versa.

"Humans have been discovering ways of tricking the mind for millennia"

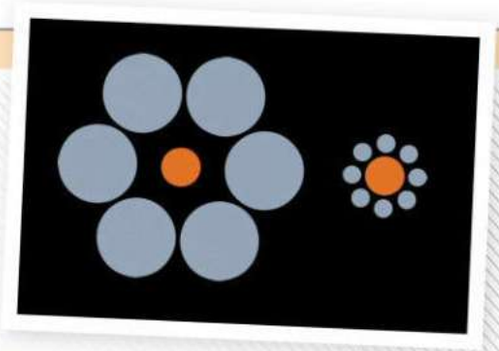
Size illusions

Discover how context can mask an object's true size

When you look at two objects next to each other, you are probably pretty confident in identifying whether they are the same size or if one is bigger than the other. However, there are certain optical illusions that prove you might not always get it right. That is because our brains often make judgements about the size of an object based on other objects that are nearby, and so can easily be fooled by context.

Take, for example, the Ebbinghaus illusion on the top right of this page. Many would consider the orange circle on the right to be larger than the one on the left, but they are in fact both exactly the same size. The brain uses the blue circles to judge the orange circles' size, and so because the blue circles on the left are larger, the left orange circle seems smaller in comparison.

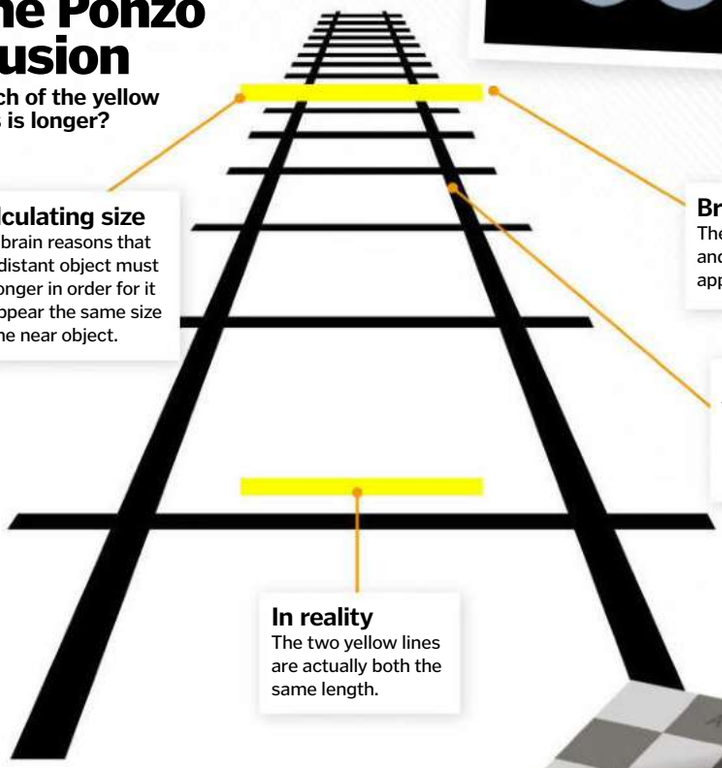
Context can also affect our brain's depth perception, making objects seem nearer or further away than they really are. This in turn can influence how we perceive their size, as illustrated by the Ponzo illusion shown here. It's this particular mind trick that makes the Moon appear bigger when it's near the horizon.



The Ebbinghaus illusion illustrates how context affects size perception

The Ponzo illusion

Which of the yellow lines is longer?



Calculating size
The brain reasons that the distant object must be longer in order for it to appear the same size as the near object.

Brain fooled
The brain overcompensates and makes the top line appear longer.

In the distance
The converging parallel lines trick the brain into believing that the top line is further away.

In reality
The two yellow lines are actually both the same length.

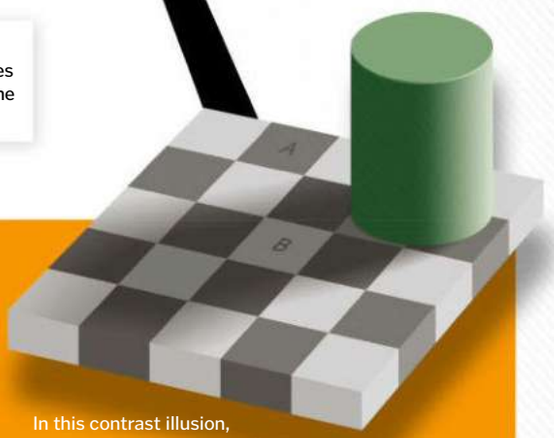
Screen flicker

If an LCD screen is filmed with a video camera, the screen often appears to flicker. This is because the screen is actually flickering in real life, and it's our eyes that are being fooled into seeing a continuous image. When a camera captures a scene, it takes a series of rapid shots and stitches them together to create a moving image. Therefore, if its frame rate does not match that of the screen it is filming, it picks up the flickering. Our eyes, on the other hand, are constantly sending information to our brains, and so hang onto an afterimage of the light from the screen in order to fill in the gaps caused by the flickering.

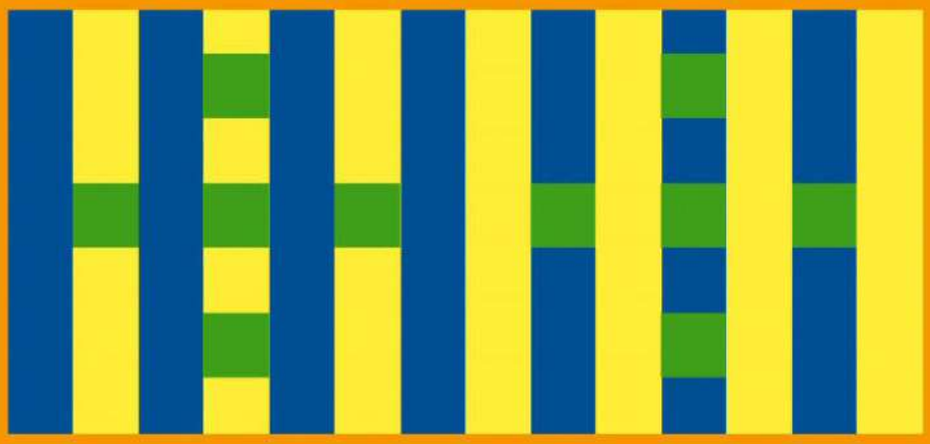
LCD screens rapidly switch their power on and off in order to regulate their brightness

Contrast illusions

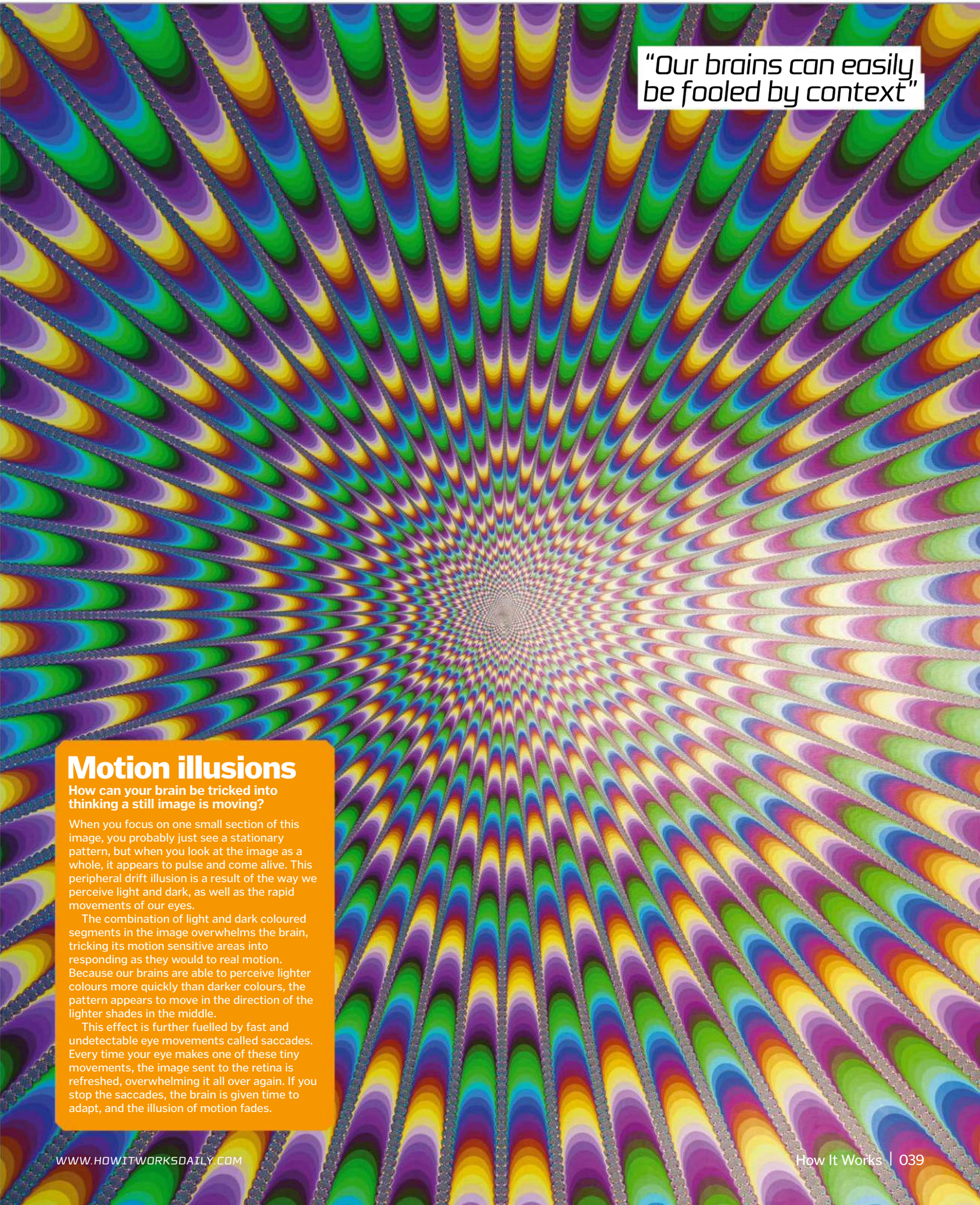
As well as altering how we perceive an object's size, context can also affect how we perceive its colour. In this image, all of the green squares are exactly the same shade, but the ones on the left appear darker than those on the right. This is because the green squares on the left are on a lighter background, creating more contrast and so making them appear darker in comparison to their surroundings. This simultaneous contrast illusion is believed to be caused by the way the retina's light-sensitive cells process two different colours next to each other. When the light reflected from a brighter background hits one of these cells, any adjacent cells are inhibited from firing off signals. This causes the light reflected from the green squares on the left to activate a stronger signal, making them appear darker.



In this contrast illusion, squares A and B are actually the same shade of grey



The green squares on the yellow background appear darker than those on the blue background



"Our brains can easily be fooled by context"

Motion illusions

How can your brain be tricked into thinking a still image is moving?

When you focus on one small section of this image, you probably just see a stationary pattern, but when you look at the image as a whole, it appears to pulse and come alive. This peripheral drift illusion is a result of the way we perceive light and dark, as well as the rapid movements of our eyes.

The combination of light and dark coloured segments in the image overwhelms the brain, tricking its motion sensitive areas into responding as they would to real motion. Because our brains are able to perceive lighter colours more quickly than darker colours, the pattern appears to move in the direction of the lighter shades in the middle.

This effect is further fuelled by fast and undetectable eye movements called saccades. Every time your eye makes one of these tiny movements, the image sent to the retina is refreshed, overwhelming it all over again. If you stop the saccades, the brain is given time to adapt, and the illusion of motion fades.

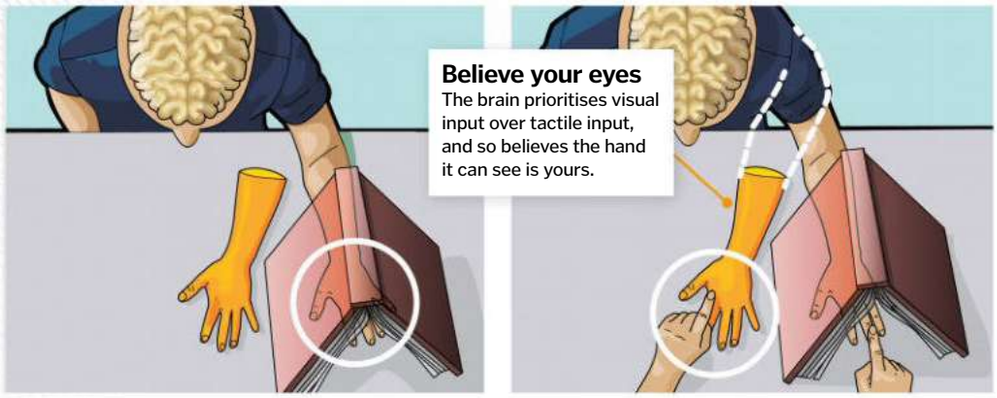
Horizontal lines on clothing affect how our eyes view people's body shape

Tricking your body

Fooling your brain can help reduce physical pain and even create pain when there is none

Rubber hand illusion

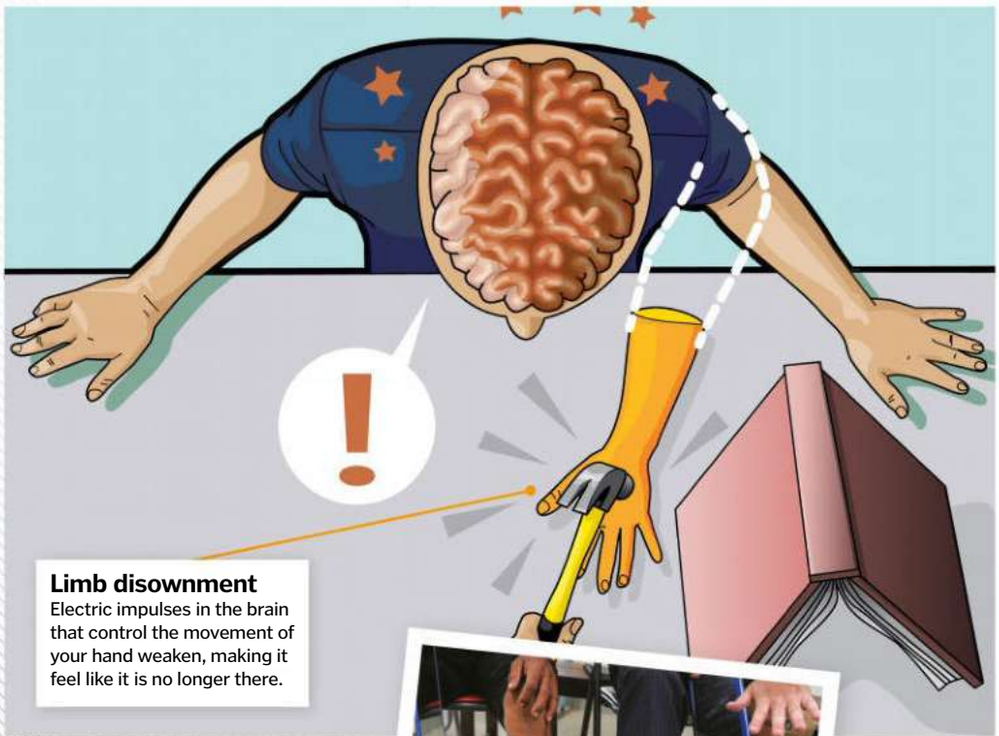
Trick your mind into believing that a fake hand is your own



Believe your eyes
The brain prioritises visual input over tactile input, and so believes the hand it can see is yours.

1 Hide your hand
Place an open book on the table in front of you, then sit with one hand underneath the book so that you cannot see it. Put the rubber hand in front of you so that it is lined up with your shoulder. Covering your arm and the 'arm' of the fake hand with a cloth will help the illusion.

2 Start stroking
Get a friend to stroke the middle finger of your real hand and the middle finger of the fake hand at the same time. After one or two minutes you will start to feel like the fake hand is your own and that your real hand no longer exists.



Limb disownment
Electric impulses in the brain that control the movement of your hand weaken, making it feel like it is no longer there.

3 Inflict some pain
Get your friend to then hit the rubber hand with a hammer. You should feel a brief jolt of pain as your brain combines visual and physical information to create a feeling of ownership over the fake hand.

Body illusions can be used to help amputees alleviate phantom limb pain

Mirror therapy

The ability to fool the brain into experiencing ownership of a fake body part is proving useful for helping patients with phantom limb pain – the feeling of pain in an amputated or paralysed limb. By placing the affected limb behind a mirror and then moving the opposite, unaffected limb in front of the mirror, the brain can be tricked into thinking the reflection is a real moving body part. This enables the patient to mentally move their phantom limb, perhaps unclenching it from a painful position to provide relief. The illusion works because the brain prioritises visual feedback over tactile feedback and so the observation of movement still manages to stimulate the processes in the brain involved in real movement.

Mirror therapy tricks the brain into thinking a reflected limb is real

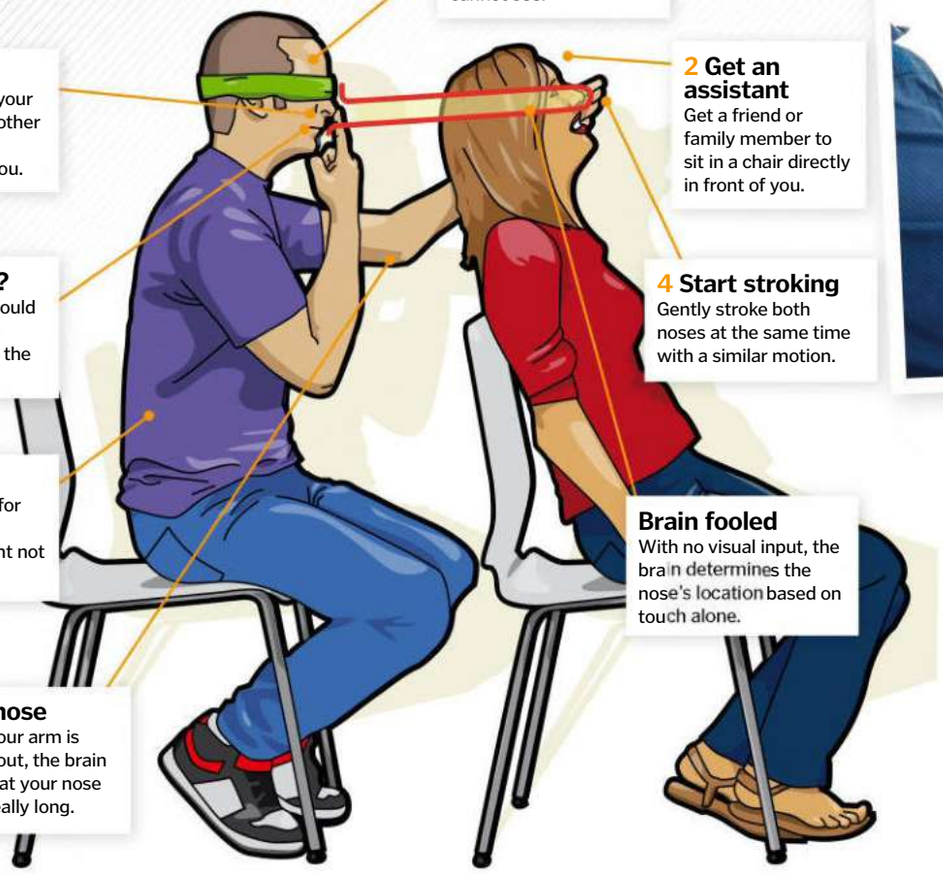
Shrinking pain

The brain's tendency to prioritise visual input over tactile input makes it possible to manipulate the experience of pain. In a study conducted by researchers at Oxford University, participants suffering from chronic pain in their right arm were asked to move the limb while looking at it through a pair of binoculars. They were then asked to do the same again, but while looking through the other end of the binoculars. When presented with a magnified view of their arm, every participant reported experiencing an increase in pain, but when their arm looked smaller or further away, the pain, and even the swelling, increased significantly less. Exactly how this illusion works remains unclear. One theory is that magnifying the arm enhances the sense of touch, while another suggests that by 'minifying' the limb, the brain's sense of ownership of it is reduced, thus desensitising it to the pain.

Binoculars have been proven to help reduce physical pain

The Pinocchio illusion

Experience the feeling of having an extremely long nose. It's no lie!



1 Wear a blindfold
Sit in a chair and cover your eyes with a blindfold so that you cannot see.

2 Get an assistant
Get a friend or family member to sit in a chair directly in front of you.

3 Hold noses
Place one hand on your own nose, and the other on the nose of the person in front of you.

4 Start stroking
Gently stroke both noses at the same time with a similar motion.

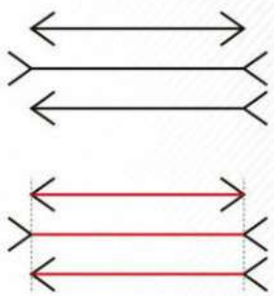
5 Which nose?
After a minute it should feel as though both hands are touching the same nose.

Success rate
This illusion works for over 50 per cent of people, so you might not feel any effect.

Brain fooled
With no visual input, the brain determines the nose's location based on touch alone.

A long nose
Because your arm is stretched out, the brain reasons that your nose must be really long.

The rubber hand illusion can fool our brains into 'adopting' an additional, artificial limb as our own



The Müller Lyer illusion features three arrows of the same length, but some appear longer than others

"The brain prioritises visual feedback over tactile feedback"

What is the funny bone?

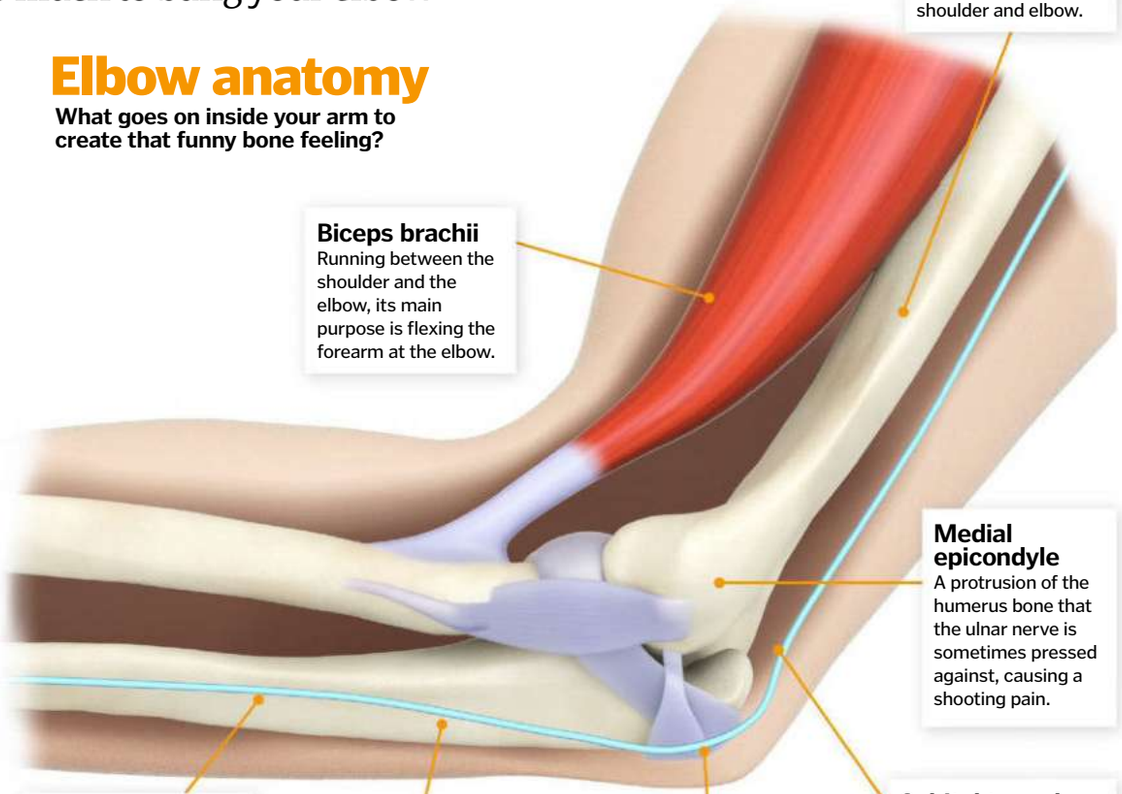
Discover why it hurts so much to bang your elbow

That unpleasant tingling feeling you get when you knock your 'funny bone' doesn't actually come from a bone at all. Instead it stems from the ulnar nerve, which runs from your neck down to your hands. This nerve is mostly protected by layers of bone and muscle, but at the elbow it passes through the cubital tunnel, where there is only skin for it to hide behind. Therefore, when you hit your arm at just the wrong angle, the nerve is compressed between the skin and a knob of bone called the medial epicondyle, causing it to send a shooting pain down your arm and into your fingers.

Hitting your ulnar nerve sends a weird tingling feeling down your arm

Elbow anatomy

What goes on inside your arm to create that funny bone feeling?



Humerus
This is the long bone in the arm that protects the ulnar nerve between the shoulder and elbow.

Biceps brachii
Running between the shoulder and the elbow, its main purpose is flexing the forearm at the elbow.

Medial epicondyle
A protrusion of the humerus bone that the ulnar nerve is sometimes pressed against, causing a shooting pain.

Cubital tunnel
The ulnar nerve passes through this small, 4mm-long channel at the elbow.

Olecranon
A bony protrusion where the radius and ulna bones meet the humerus bone.

Ulnar nerve
This string of sensitive fibres sends signals to and from the muscles in your arms and hands.

Ulna
This is the bone in your forearm that runs parallel to the radius and protects the ulnar nerve.

Hand warmers

Discover the chemical reactions that keep your fingers toasty in the cold

Hand warmers were originally created by Japanese inventor Niichi Matoba in 1923

When you're reaching for a heat pack that will thaw your frozen digits, there are two main types you can choose from.

Disposable hand warmers use a reaction called oxidation – the same process that creates rust. When you remove the outer packaging, oxygen from the air seeps in through tiny holes in the pouch, oxidising the iron powder inside and generating heat. Salt is added to speed up the reaction, while carbon helps to spread the heat evenly, and vermiculite prevents it from escaping too quickly.

Reusable hand warmers use a different – and reversible – chemical reaction. Inside the pouch is a small metal disc surrounded by a supersaturated solution of sodium acetate crystals dissolved in water. The liquid sodium acetate is able to hold onto the heat energy used to dissolve it, but when the metal disc is snapped it turns back into a solid and releases that heat to warm your hands. To reuse it, you just need to boil the pouch in water. This reverses the chemical reaction, dissolving the sodium acetate crystals back into a liquid solution.

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Vitamins and minerals explained

What are micronutrients, and where can you find them?

Vitamins and minerals are essential nutrients. The body needs them to survive, but in much smaller amounts than nutrients like protein, carbohydrates and fats.

The body is made of cells, which are essentially tiny molecular factories. They are surrounded by a fatty membrane, they use carbohydrates for fuel, and most of the molecules they produce come in the form of proteins. So, the body needs large amounts of fats, carbs and proteins to survive, but it also requires small quantities of micronutrients. Vitamins and minerals are used to produce crucial molecules like enzymes and hormones, which help the body to maintain its balance of fluids, to send short- and long-distance signals, and to strengthen and repair tissues.

Vitamins are organic and made by other living organisms, while minerals are inorganic – most often metals – and are found in the soil. The human body cannot produce them by itself, so we need to take them in through our diets.

There are two main types of vitamin, categorised according to how they dissolve. Fat soluble vitamins can be found in foods like oils, dairy products, eggs, liver and fish, and they are also stored in the fats inside the body. This helps to prevent deficiency, but it means that it is possible to overdose if you eat too much. In contrast, water soluble vitamins cannot be stored by the body. They are found in fruits, vegetables, grains and dairy products, and any excess is rapidly excreted in the urine. This makes it harder to overdose, but easier to become deficient.

Luckily, a healthy, balanced diet is usually enough to ensure that you have the right mixture of vitamins and minerals to keep your body functioning normally.

Vitamin B2 aka riboflavin
Milk, eggs, fortified cereals
B2 is involved in releasing energy, and it's also an antioxidant that helps to scavenge free radicals.

Vitamin B12
Meat, fish, milk
B12 is involved in healthy nerves and red blood cells, and helps the body process folic acid.

Vitamin D
Oily fish, red meat, made from sunshine
This vitamin is important in maintaining the right amount of calcium and phosphate, critical for strong bones.

Vitamin B5 aka pantothenic acid
Chicken, beef, potatoes
B5 is used to make Coenzyme A, which breaks down fats and carbs.

Phosphorous
Red meat, poultry, oats
This mineral is found in every cell in the body, and it helps strengthen bones.

Zinc
Meat, shellfish, wheat germ
Zinc is important for making new cells and enzymes.

Vitamin B6 aka pyridoxine
Pork, chicken, fish
B6 is involved in the storage of energy, and in making red blood cells.

Vitamin A
Eggs, cheese, oily fish
Vitamin A is needed for the production of light-sensitive pigments in the eye. It's also involved in immune function and skin health.

Vitamin C aka ascorbic acid
Citrus fruits, strawberries, blackcurrants
This vitamin is involved in the production of collagen, which supports the skin and other tissues.

Vitamin B3 aka niacin
Liver, fish, wheat, sunflower seeds
B3 is involved in breaking carbohydrates down into the simple sugar glucose.

Vitamin E
Plant oils, nuts, seeds
Vitamin E is an antioxidant that helps to neutralise free radicals. It's important for skin, eyes and the immune system.

Folic acid aka folate
Broccoli, sprouts, liver
Folic acid is involved in the development of the nervous system – crucial during pregnancy.

Potassium
Bananas, broccoli, pulses
Potassium works with sodium to pass signals along the nerve cells, helping the heart to function.

Molybdenum
Nuts, cereals, peas, beans
Molybdenum helps enzymes involved with making and repairing genetic materials.

Vitamin B1 aka thiamin
Fortified cereals, nuts and meats
The first of eight B vitamins involved in breaking down fats and carbs to release energy.

Chromium
Meat, whole grains, broccoli
Chromium is involved in insulin signalling and maintaining blood sugar levels.

Copper
Nuts, shellfish, offal
This metal is involved in making blood cells.

Vitamin B7 aka biotin
Eggs, nuts, whole grains
This vitamin is essential for the metabolism of fat.

Selenium
Brazil nuts, fish, meat
Selenium is an ingredient in enzymes that help prevent cell damage.

Vitamin K
Green leafy vegetables, cereals
Vitamin K is crucial for blood clotting. It is a component of many of the clotting factors that help to stop bleeding after injury. It also plays a role in bone health.

Manganese
Tea, cereals, peas
Manganese helps with clotting and is important in connective tissue and bone.

Calcium
Dairy products, green leafy vegetables, soya beans
This is the most abundant mineral in the body. It is used to build strong bones, and is involved in the signals that contract and relax muscles.

Iodine
Seafood, iodised table salt
Iodine is vital for making thyroid hormones, which are responsible for regulating metabolism.

Magnesium
Green leafy vegetables, brown rice, whole grains
This mineral helps the parathyroid glands produce hormones important for bone health.

Iron
Meat, beans, dark green leafy vegetables
Iron is a key component of haemoglobin – the red pigment that carries oxygen around the blood.

Sodium
Table salt
Salt contains sodium and chloride, both crucial for fluid balance, and sodium is vital for nerve signalling.

KEY:
V Vitamin
M Mineral

Brain cells

Find out what's really going on inside your head

Your brain is an incredible thing. It is one of the most complex structures in the known universe, and for decades, scientists have been teasing it apart to find out what it's made of and how it works.

The brain is an electrical and chemical circuit, and nerve cells, or neurons, are the components. They each have a cell body, which contains their genetic code, an axon to transmit electrical impulses, and dendrites to receive them.

They are connected together at junctions known as synapses. When an impulse arrives, packets of molecules are released, passing the message on. Each neuron makes hundreds, or even thousands, of connections, producing the complicated patterns that drive human thought.

There are hundreds of different types of neuron in the brain, categorised according to their unique structure and function, and more are being discovered all the time. But they can't function on their own. They are supported by a network of glial cells – a name that literally means 'glue'.

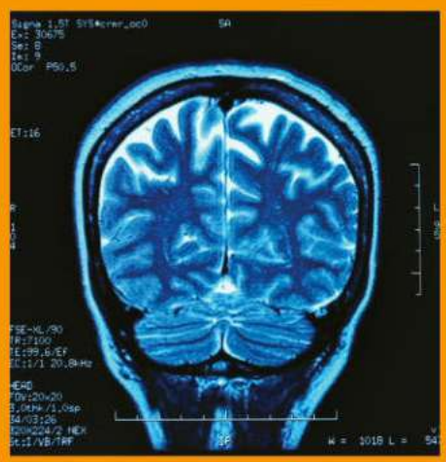
There are three main types of glial cell. Oligodendrocytes have fatty branches, which they wrap around the conducting axons of nerve cells like the plastic coating on electrical wires. This provides insulation, preventing signals from getting crossed and speeding up their transmission along the chain.

Microglia are part of the immune system and act like an in-house cleanup crew, tracking down pathogens and clearing debris from the brain. Then there's the star-shaped astrocytes, which reach between nerve cells and blood vessels with their long, thin arms, shuttling nutrients, mopping up waste products, and even getting involved with chemical signalling.

How many cells?

It's hard to know exactly how many cells are in the brain. Individual neurons have long, thin axons and branching trees of dendrites that cross over with their neighbours, forming a tangled mass that is almost impossible to accurately examine. One of the most commonly quoted estimates is 100 billion neurons, with anywhere between three and ten times as many supporting glial cells, but the latest research suggests that these numbers are in fact wrong.

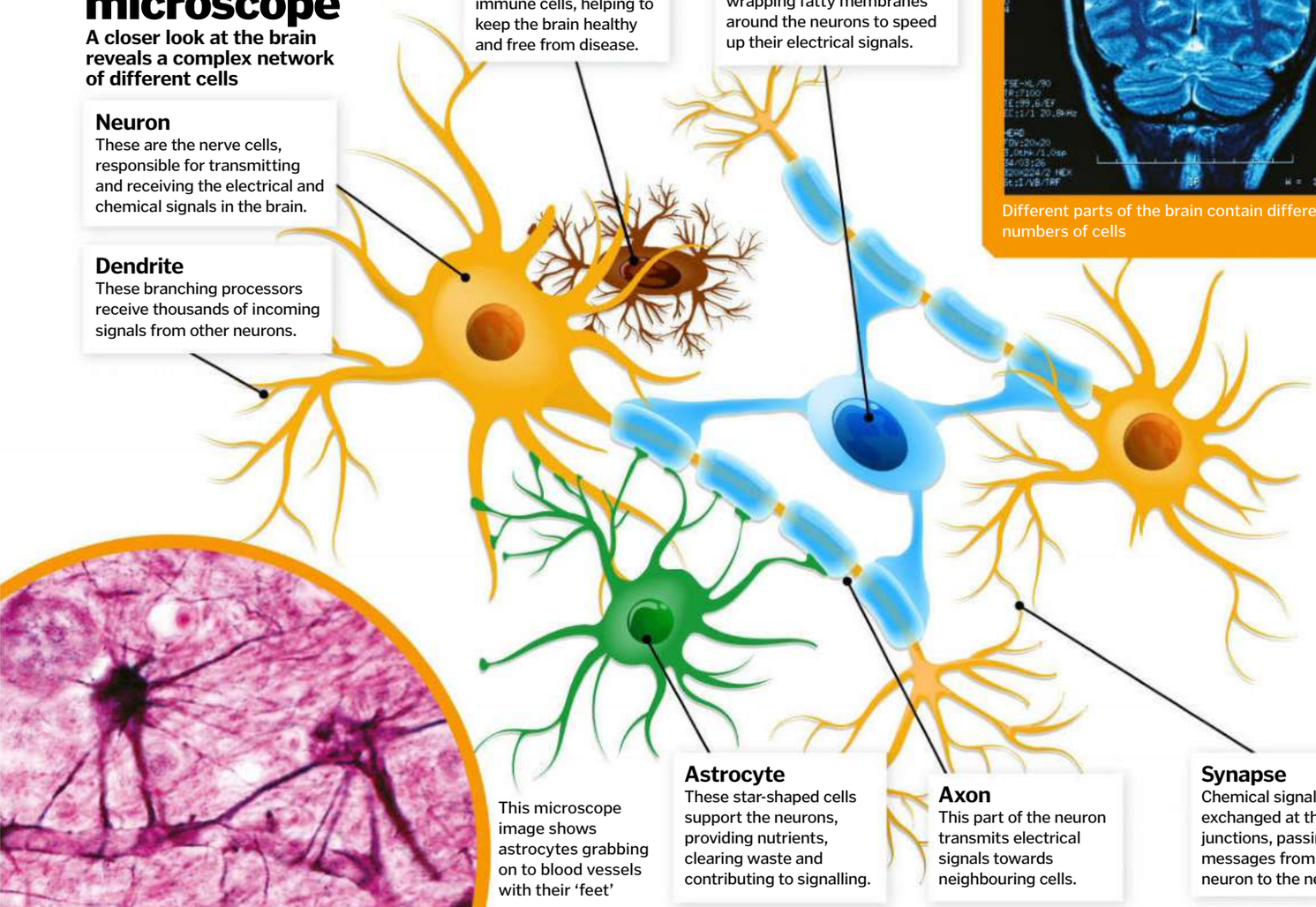
Using a new technique for counting cells, scientists have come up with a different number. Each cell has one nucleus, and they can be stained up to make it easy to tell whether they belong to a neuron or a glial cell. Rather than count them under a microscope, the researchers popped the cells open and turned them into a 'soup' so that they could be quickly counted by machine. Using this technique, they revealed that there are closer to 86 billion neurons and about the same number of glial cells – far fewer than expected.



Different parts of the brain contain different numbers of cells

Under the microscope

A closer look at the brain reveals a complex network of different cells



Microglia
These are specialist immune cells, helping to keep the brain healthy and free from disease.

Oligodendrocyte
These cells provide insulation, wrapping fatty membranes around the neurons to speed up their electrical signals.

Neuron
These are the nerve cells, responsible for transmitting and receiving the electrical and chemical signals in the brain.

Dendrite
These branching processors receive thousands of incoming signals from other neurons.

This microscope image shows astrocytes grabbing on to blood vessels with their 'feet'

Astrocyte
These star-shaped cells support the neurons, providing nutrients, clearing waste and contributing to signalling.

Axon
This part of the neuron transmits electrical signals towards neighbouring cells.

Synapse
Chemical signals are exchanged at these junctions, passing messages from one neuron to the next.

Pressure suits

How pressurised clothing enables pilots to soar high up into the atmosphere

At altitudes of 15,000 metres or more both oxygen and pressure levels decrease significantly. The air is so thin that if an aircraft cockpit is depressurised, a pressure suit is needed to survive. There are two types: partial and full. When depressurisation occurs, a partial pressure suit tightens as the capstans, or bladders, that are attached to the suit inflate. Both the sensation and the process are similar to how a cuff feels around your arm when a doctor measures blood pressure. The fabric around the thorax and the major muscle groups is constricted, creating counterpressure that prevents the body from swelling uncontrollably. Pilots can still breathe effectively and move their limbs freely as oxygen is provided through the helmet. It remains tight until the aircraft is able to descend safely to a lower altitude.

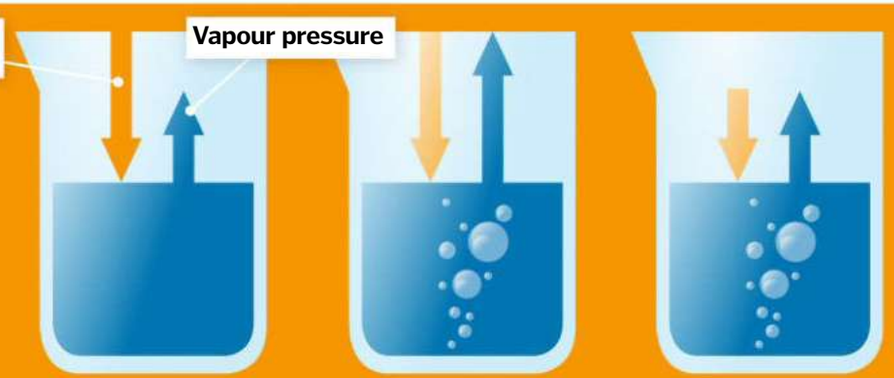
Full pressure suits are made from fire-resistant materials like Nomex. Rather than putting actual mechanical pressure on the body, these suits envelop a pilot in a layer of air. This is an artificial atmosphere that the pilot is able to breathe and function in. It's like an air filled balloon surrounding the body. They have anti-g layers built into them, which neutralises the strain exerted on the body by fighter jet manoeuvres and space rocket launches. As this suit doesn't directly pressurise the body, it can be worn for much longer, and some even have straws installed so pilots can eat and drink on long flights without taking off their helmet.

Astronauts require full-pressure suits when conducting extravehicular activities (spacewalks)

Why is the water boiling?

The main image (above) was taken during an experiment by the US Air Force in the 1950s as they were investigating the limits of human flight. It shows a man testing a partial pressure suit in a chamber designed to simulate an altitude of nearly 20,000 metres. But why is the water in the container boiling? This phenomena is a result of the fact that boiling point and atmospheric pressure are linked.

A liquid will boil when its vapour pressure (the tendency of its molecules to escape the liquid's surface to become a gas, which increases with temperature) is equal to atmospheric pressure. Therefore the lower the atmospheric pressure, the less energy (and so a lower temperature) is required for a liquid to boil. For example, water boils at 100 degrees Celsius at sea level, but if you were to climb to the top of Everest, you'd find that water boils at just below 70 degrees Celsius.



Normal conditions
At room temperature at sea level, water doesn't boil because the vapour pressure is lower than the atmospheric pressure.

Boiling point
At sea level, raising water temperature to 100°C increases its vapour pressure to equal atmospheric pressure, boiling it.

Low pressure
Under low pressure conditions, liquids boil at lower temperatures because less energy is required for the water to vapourise.

Elements, mixtures and compounds

What are the differences between these configurations of atoms?

All matter is made of atoms – tiny particles that cannot be seen through the lense of a conventional microscope.

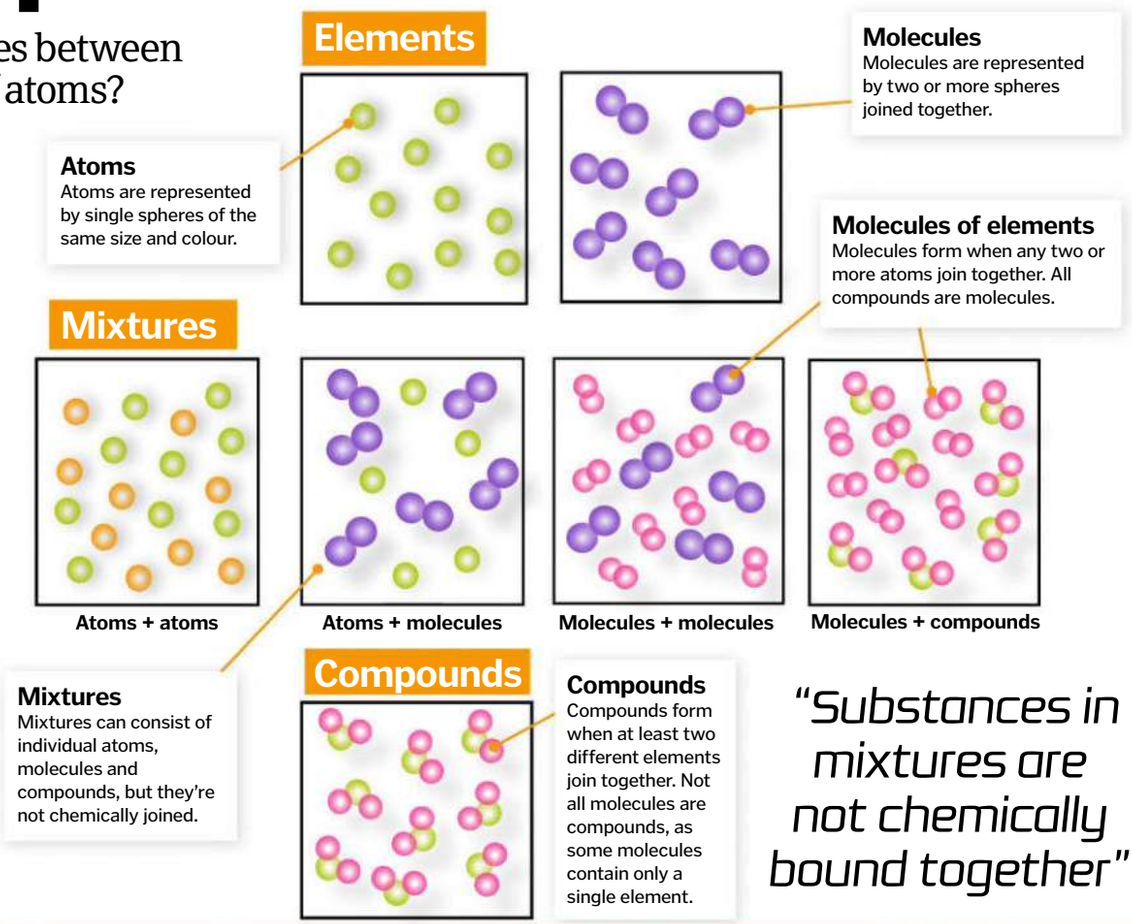
Atoms make up the table of elements, and all elements are made up of the same parts: protons, neutrons and electrons. The atoms of a particular element are all the same as each other, as they all contain the same number of protons in their nuclei.

A compound contains atoms of two or more different elements, which are chemically joined together. Water is a compound that contains two hydrogen atoms and one oxygen atom.

A mixture is a substance consisting of different atoms, molecules or compounds that aren't chemically joined. Air, for example, is a mixture of nitrogen, oxygen, argon and others.

How do they differ?

A guide to how atoms make up elements, mixtures and compounds



"Substances in mixtures are not chemically bound together"

Limescale

Discover what causes limescale and how chemical descalers can remove it

Limescale is a crusty, off-white deposit of calcium carbonate left behind by hard water, and mostly found in your kettle and boiler. Hard water contains an above average concentration of dissolved minerals, like calcium and magnesium ions. Limescale becomes an issue when hard water is heated or left to stand. When the moisture evaporates, the dissolved minerals solidify and turn to limescale, which is difficult to remove. A build-up of limescale in central heating pipes, washing machines and dishwashers can restrict water flow, making them less efficient and can even clog them up completely.

Fortunately, there are ways to remove limescale. For example, ion exchange columns contain ion exchange resin in the form of beads. As water passes through the column, the calcium and magnesium ions in the water swap places with the ions in the column, gradually removing the unwanted minerals. Citric acid, sesquicarbonate and other compounds can also be found in water-softening agents, which prevent the calcium and magnesium ions from forming limescale deposits. Acids are used in most limescale removers because they react with limescale and produce soluble metal salts that can be washed away.

60 SECOND SCIENCE

Heat transfer

GET THE 60-SECOND LOWDOWN ON HOW HEAT GETS FROM A TO B

BACKGROUND

Our universe is made up of matter and energy, and its countless particles are constantly in motion. You can measure this motion with a thermometer. The temperature tells you the average kinetic (movement) energy – the more the particles are moving, the higher the temperature will be.

Heat is the transfer of this energy from one place to another. If an object feels warm, it's because it is transferring energy to your body. This can happen in three ways: conduction, convection and radiation. This understanding of heat developed in the 1800s and overturned many now obsolete theories that were proposed before it.

IN BRIEF

Conduction is the transfer of heat through solids by the movement of particles. Heat energy is transferred by movement, and if moving particles bash into each other, they pass some of their energy on. Metals are particularly good at conducting heat because they have free electrons that can move around inside, taking heat energy with them.

Convection happens in fluids. When liquids and gasses are heated, the particles inside them move faster. This causes the warm fluid to expand and become less dense, rising above the colder fluid. As the colder fluid is heated, it expands and rises, and as the warm fluid cools, it contracts and falls, creating convection currents.

All objects also emit infrared radiation. The higher the temperature, the more radiation is released. These electromagnetic waves can travel through a vacuum, allowing heat to be transferred even in space.

SUMMARY

Heat is the transfer of energy by conduction or convection, which both involve particles, or by radiation, a process that involves electromagnetic waves, which are capable of travelling through a vacuum.

Heat transfer in action

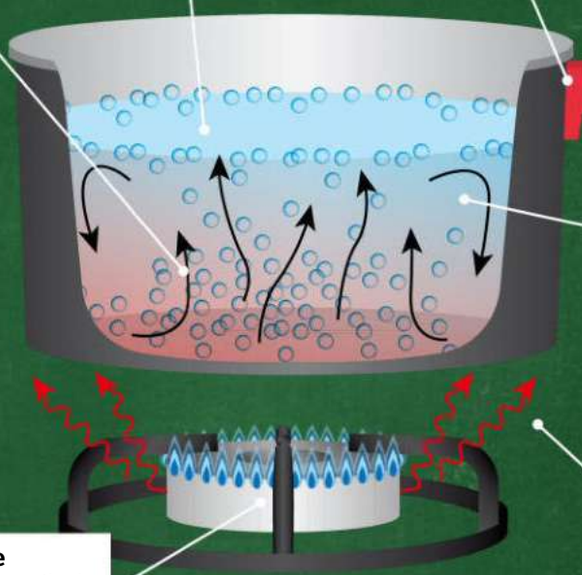
Boiling a pan of water uses all three methods of heat transfer

Infrared cameras reveal the thermal radiation emitted by different objects

Expansion
The fast-moving water molecules get further apart and the heated water becomes less dense.

Conduction
The free electrons in the metal pan transfer heat by bumping into molecules and setting them vibrating.

Convection
As the water at the bottom of the pan heats up, the molecules move faster.



Convection currents
The cool water drops to the bottom of the pan, before being heated and rising to the top.

Heat source
The combustion reaction in the fire converts chemical energy to thermal energy.

Radiation
Infrared radiation from the flames travels through the air, colliding with the metal of the pan.

THE FIRST LAW OF THERMODYNAMICS

THERMODYNAMICS IS THE SCIENCE OF ENERGY AND WORK. IN 1850, SCIENTISTS RUDOLF CLAUSIUS AND WILLIAM THOMSON, (BARON KELVIN, AFTER WHOM THE UNIT KELVIN IS NAMED) STATED THE FIRST LAW OF THERMODYNAMICS, WHICH DESCRIBES ENERGY CONSERVATION. ENERGY CANNOT BE CREATED OR DESTROYED, BUT IT CAN TRAVEL FROM ONE PLACE TO ANOTHER. IT CAN ALSO BE CONVERTED INTO OTHER TYPES OF ENERGY LIKE CHEMICAL, ELECTRICAL, LIGHT AND SOUND.

THE FIRST LAW STATES THAT THE AMOUNT OF ENERGY IN A SYSTEM IS EQUAL TO THE HEAT TRANSFER MINUS THE WORK DONE. FOR EXAMPLE, IN A CAR ENGINE, A SPARK IGNITES PETROL GAS, CONVERTING CHEMICAL ENERGY INTO THERMAL ENERGY AND CAUSING THE GAS TO EXPAND INSIDE A CLOSED CYLINDER. THIS PUSHES AGAINST A PISTON AND, AS THE PISTON MOVES, IT TURNS THE CRANKSHAFT. THE THERMAL ENERGY IS CONVERTED INTO KINETIC ENERGY TO MOVE THE CAR.

HI-TECH FITNESS

The future gadgets that will help you get fit and healthy

Technology makes staying fit easier, there's no doubt about it. Whether you wear a tracker on your wrist to monitor your heart rate and calorie burn, or use an app to track running or cycling sessions, there are clear benefits for tooling up before you work out. With fitness trackers still only in their infancy, and technologies like virtual reality and artificial intelligence quickly improving, the future of fitness gadgets will take these simple apps and trackers to a whole new level.

First and foremost, the future of fitness will almost certainly revolve around data analysis. Yes, we can already hear you yawning, but bear with us. We already track our workouts to see how our fitness improves over time, whether it's bike rides, gym sessions or marathons. Smartphone apps, which take advantage of the device's GPS chip, as well as various accelerometers and gyroscopes, pick up all kinds of movements to give us a good idea of how well we're performing. But there are plenty more trackers available, which can check our heart rates and analyse speed, along with many other stats. As measurements become more easily available our ability to examine our fitness will improve. Soon we'll be able to check out our muscle tone using devices like the Skulpt Scanner, which analyses 24 locations in the body to show you the fat percentage and rating of certain muscles. The device measures the quality of specific muscles using a method called composition myography. It effectively sends a small current through each muscle. Body fat and muscle affect this current in different ways, and the change is monitored by electrodes to provide a readout of your muscle's condition. It will also soon be possible to accurately measure the amount of

AI personal trainers

With digital assistants like Siri, Cortana, and Google Assistant already in the devices we carry around with us every day, it was only a matter of time until fitness-focused AI gained momentum. Artificial personal trainers, like the Vi neckband, allow users to get personalised workouts, live data about their heart rate and pace, and high-quality audio all in one device. The voice of the Vi will push you to beat your personal best, tell you if you're running a little slower than normal, and check whether you want to stop your workout when you get tired.

The device learns more about you every day by tracking your workouts and measuring improvements. You can wear the neckband all day too, listening to music and making phone calls wirelessly when you're not exercising. As this kind of technology becomes smaller and more portable, these smart workout assistants will only get better, but the Vi is a great start.

The Vi sits around your neck, so you can wear it for long periods without it getting in the way

Inside the Vi headset

Take a look at the tech behind the smart workout assistant

Microphone
The built-in microphone means you can speak to Vi ask it questions, and make phone calls.

Magnetic
The magnets at the end of the Vi allow the headphones to attach to the neckband, and the ends to clip together.

Premium sound
The headphones attached to the Vi are produced by Harmon Kardon, a high-end audio company.

Stay connected
The antenna will connect to your smartphone, so your workouts will be saved.

Sensing everything
Sensors like a barometer and heart rate sensor built into the headphones will help record lots of data.

All-day battery
The battery takes up one side of the neck band, and should last for around eight hours on a full charge.

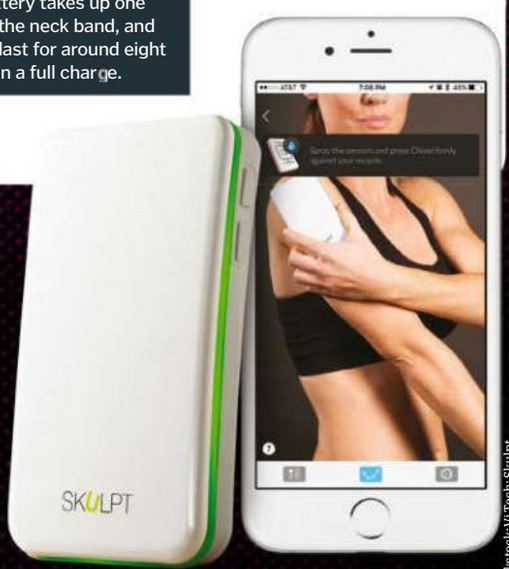
Simple interface
Three buttons on the neck band will allow you to easily interact with the Vi when voice control isn't possible.

"The Vi learns more about you every day by tracking your workouts"

body fat you burn when you exercise, and track your respiration. Samsung's Body Compass 2.0 uses smart clothing, with six different types of sensor built into the clothes themselves to track these readings and provide you with feedback, letting you know if you're exercising properly. It's still very much a prototype, but with developments like these we could see similar smart clothing hitting the shelves very soon.

People involved in more contact-heavy sports also have a brighter future thanks to devices intended to monitor – or protect against – injuries. One example is the FitGuard. This connected gumshield can measure the impact of each collision, and links with an app to monitor users for head injuries. For those that play rugby or American football, tech like this could be a huge help in detecting injuries that might otherwise go unnoticed. There are approximately 3.8 million sports-related concussions per year, but many athletes do not report their symptoms, putting their health at risk. The company behind FitGuard hope their device will help solve this problem.

As we work out more and more, the data we collect from these devices, and the others that



Measuring muscle tone is now as simple as holding a Skulpt to your skin

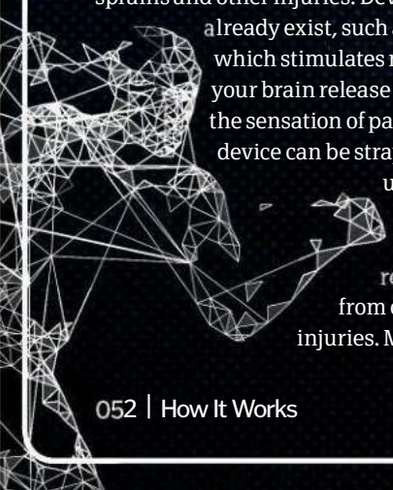
follow on from them, will be combined to form a complete picture of our bodies. What's more, a full analysis of our workouts and health has far-reaching benefits. Doctors will be able to find out more about us and our bodies before we even go in for a check-up. And with problems being flagged immediately and relevant advice made available to you online, there may be less need for a doctor's input. As healthcare becomes more personal and more available, health services will be put under less of a strain.

But this data can be used for more than just health checks. As artificial intelligence improves, computers will get better at analysing your workouts, your body and your own goals, and will be able to create truly personalised workout regimes that you can follow without ever needing to pay for a personal trainer. These computers will be able to recommend exercises that improve on specific areas of your fitness, whether it's fat burning or toning certain muscles in your body. As you start to work on them you will be able to see exactly how well you're progressing over time. The computer will analyse your results and recommend more workouts, whether it's to continue to improve in specific areas or to maintain your current form.

In time, the tech needed to do this will also be built into the clothes we wear to exercise. Companies like Under Armour have created connected shoes, called SpeedForm Gemini 3 RE, which track your pace, stride and more. Soon these kinds of trackers will be built into workout shirts, shorts and other wearables like headphones and wristbands.

The same sort of technology might well be built into our pyjamas too. It might sound strange, but getting a good night's sleep is essential to living healthily, and improving your sleep can have big impacts on your body. You can already use trackers to monitor the duration and quality of your sleep, and as these sensors get smaller, cheaper and easier to wear they will become more commonplace.

Of course, the workout doesn't stop when you finish a session. New technology will also aid budding athletes in their recovery, improving circulation and relieving muscle pain caused by sprains and other injuries. Devices like these already exist, such as the Quell, which stimulates nerves to make your brain release chemicals to dull the sensation of pain. This portable device can be strapped onto the upper calf, and over the course of weeks can reduce discomfort from chronic pain or injuries. More intensive



Staying fit with VR

VR headsets might have a huge part to play in the future of fitness, allowing users to feel like they're playing a game, while staying fit at the same time. When paired with a system like the Icaros, this 'gameification' of fitness becomes all the more exciting. This kit makes users feel like they're flying, and as you lean in different directions your whole body will move around you. Paired with a VR headset, this experience feels even more real. But what makes the system so good is that it works out a number of muscles without you even realising.

Balancing on the system requires a strong core, and after a few minutes on the Icaros you'll soon start to feel the burn in your abs, shoulders and quads. Soon VR headsets may also be paired with smart treadmills that measure our speed and adapt their speed to match our movement.

The Icaros system is expensive, but this kind of workout experience could be the future of fitness

Devices like the FitGuard can track collisions and help to alert players to injuries instantly

Flying with Icaros

Find out how the Icaros system works and how it challenges your body

Personalised ride
You can adjust the positions of the arm and leg rests to get the best and most comfortable ride for you.

Ab workout
Your abs and shoulders will take the most strain in the Icaros system, which should help tone them.

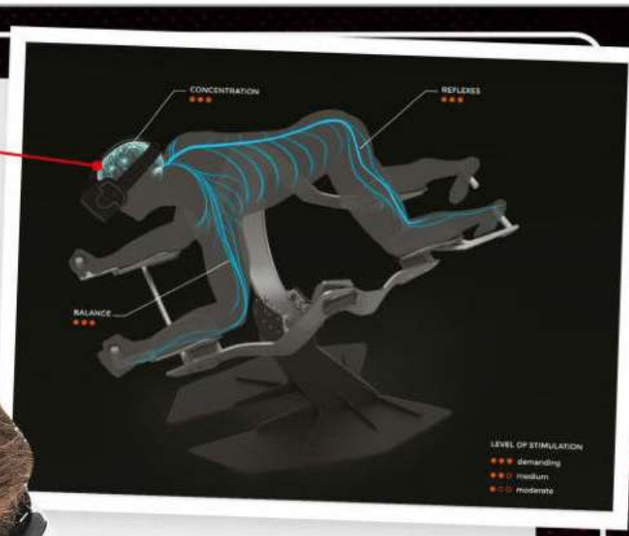
Play the game
The VR experience is a flying game that tasks you with getting through rings, but there are others available.

The Gear
The Icaros currently works with the Galaxy Gear VR headset, but HTC Vive support is coming soon.

In control
The controller on the hand grip controls the game, and links to your smartphone to feedback every movement of the Icaros.

Fly away
The Icaros, paired with the VR smartphone game, will make you feel like you actually are flying.

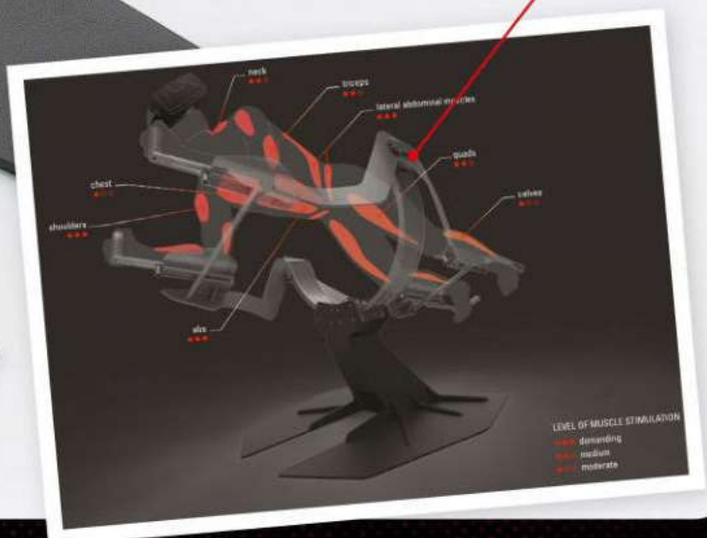
Concentration
The Icaros system works out your brain as well as your abs, as you have to concentrate to play.



Reflexes
As well as good balance, the system will help you improve your reflexes.

"Paired with a VR headset, this experience feels even more real"

Specific muscles
The system will require some physical effort to control, so your muscles will get a good workout.



Balance is key
Getting onto the Icaros properly may take some practice, but once you're on, shifting your body weight will help you balance.

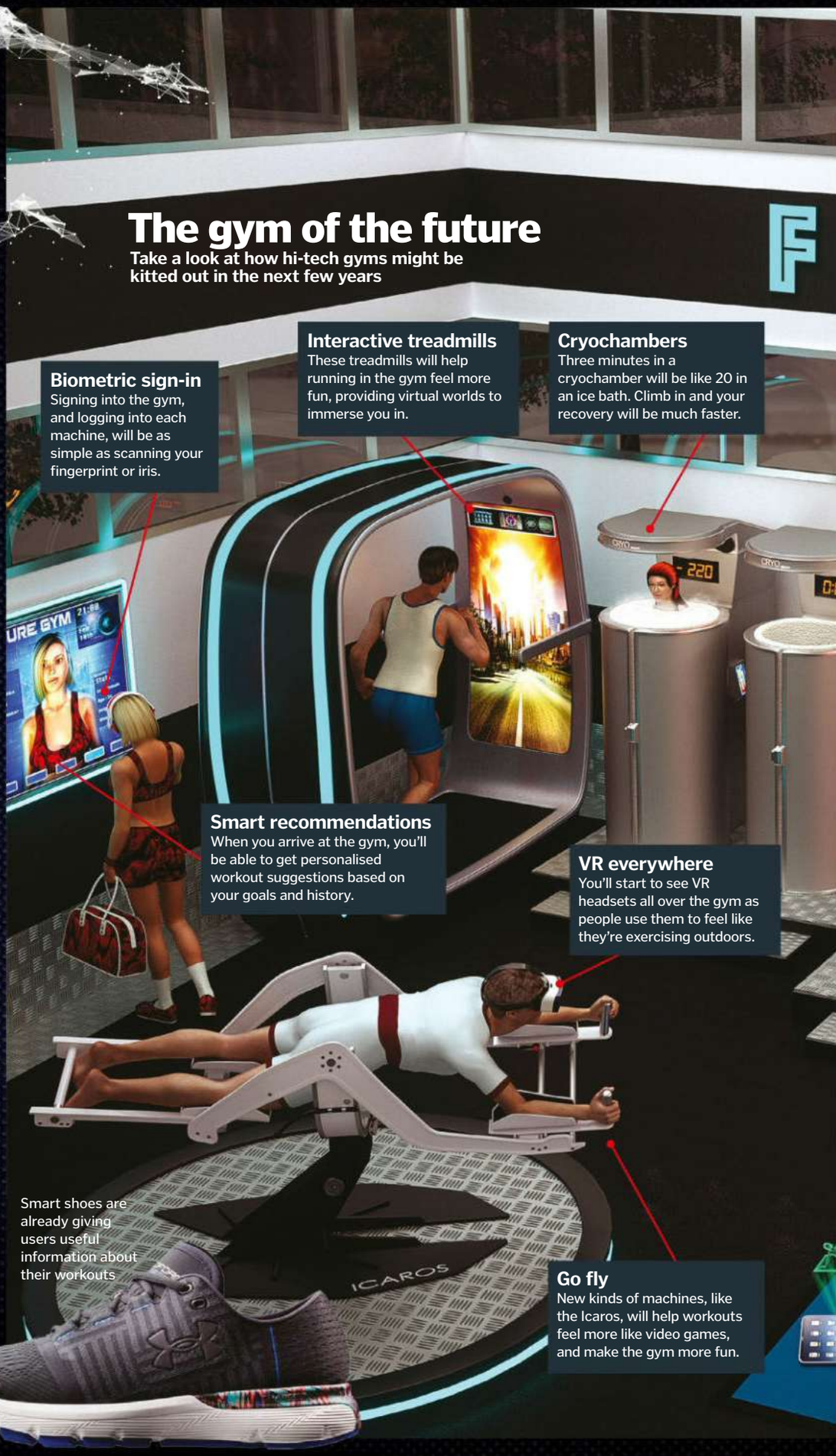
© Fitguard; Alamy; Icaros

methods, such as those on offer from the XTreemPulse PureFlow, can aid recovery immediately after exercise. After wrapping the legs in specially-designed cuffs, the PureFlow system pumps air into the cuffs, compressing areas of the leg and increasing blood flow, and therefore the flow of oxygen and nutrients, to the muscles that need it. The machine is large, and usually requires a technician to operate, meaning the PureFlow is certainly more of a specialist device, but soon the technology may be more portable and affordable, and more commonplace in gyms.

Of course, all of these gadgets focus on helping individuals to improve their workout and their bodies. But there's one hugely important aspect of fitness that will undoubtedly expand in the next few years – social fitness. As we become more connected to smart devices with all kinds of trackers, keeping fit may become more of a social experience. Some fitness apps already let you add friends and see their progress, and this will only increase as we access more metrics about ourselves. Exercise will innevitably turn into more of a competition, with workouts becoming a game that you're playing against your friends. Who reduced their body fat by the most this month? Who improved their muscle tone more? Who ran further, cycled faster or bench-pressed more? Competition is great, especially when you're trying to stay healthy, and apps and services will soon let fitness become about winning as well as working out.

Other technology may take this 'gamification' of fitness even further. Virtual reality headsets worn while working out could turn your gym into a video game world, where you see your friends running next to you in real time. Workouts will become more social as you race against friends in the game world, or try and beat the time they set a few days ago. Alternatively, your movements in the workout may be turned into other actions in the game. The faster you run, for example, the faster your avatar will complete a certain mini-game. Consoles like the Nintendo Switch and PlayStation VR already have games that have you moving in the real world, and this could simply be the next iteration of those types of game.

Many of these technologies are still in their infancy and must develop over the next few years before they become available to consumers. But with so much fitness tech on the horizon, soon we will have all the tools we need to get up and get fit.



The PlayStation VR is already helping people get more active while having fun, and it's just the start

Smart mirrors
Weight lifters will use smart mirrors, with built-in screens and digital avatars, to see if their posture and movements are correct.

Holographic instructors
When doing stretches or yoga, holographic coaches will be able to show you the correct form.

Smart sensors
Sensors like the Vi headset will be everywhere to help you improve your fitness.

Charged up
Many of the machines will be hooked up to the gym's power grid, providing free energy for the building.

"Exercise equipment can capture the energy created by people working out"

Exercise-powered gyms

Green energy is key to the survival of our planet, and every little helps. That's why some gyms are setting up their exercise equipment to capture the energy created by people working out, and using it to cut down on their electricity bill. At the moment this is mainly used on elliptical machines, but there's no real reason why the technology couldn't also be used on cross-training, rowing and cycling machines in the future. The devices are set up with a power converter and all plug into a central power unit, which can then be used to power other parts of the gym. With exercise in gyms becoming more and more popular, this seems like a great way to cut down on a little energy consumption.

Machines that capture energy, like this SportsArt G575U Cycle machine, might be the future of gyms

Inside the latest MacBook Pro

How does Apple's new laptop actually work?

Apple took a big leap of faith with the new MacBook Pro. With competitor laptops increasingly using touch-screen displays that allow users to tap on the screen like a tablet, and in some cases detach the screen so it literally becomes one, Apple stuck to its guns. Rather than making the new MacBook's display a touch-screen, the company instead decided to add a touch bar to the top of the laptop's keyboard. This bar is really just a long, thin touch-screen, and can display all kinds of extra controls and shortcuts depending on what apps you're using on-screen. Tap or drag across it and you can use these features without having to dig through menus to find the thing you need – it's right at your fingertips.

There are plenty of other improvements too. There's a Touch ID sensor on the far right of the Touch Bar, which allows you to unlock or sign into your laptop with just your fingerprint. It also helps you purchase things online in seconds using Apple Pay. The trackpad below the keyboard is large and pressure sensitive. This means you can press more firmly to access different options. The trackpad itself uses tiny vibrations, called haptic feedback, to let you know when you're clicking or pressing firmly. An upgraded Retina display provides some stunning images, with so many pixels packed in that you may forget you're looking at a screen.

The question is, how does Apple get so much tech into such a portable device?

The Touch Bar sits at the top of the laptop's keyboard, in the place the function keys would normally be

MacBook Pro teardown

Take a look inside Apple's latest smartbook

Batteries
One of the biggest challenges in thin laptops is fitting in powerful batteries, which is why these flat batteries take up so much space.

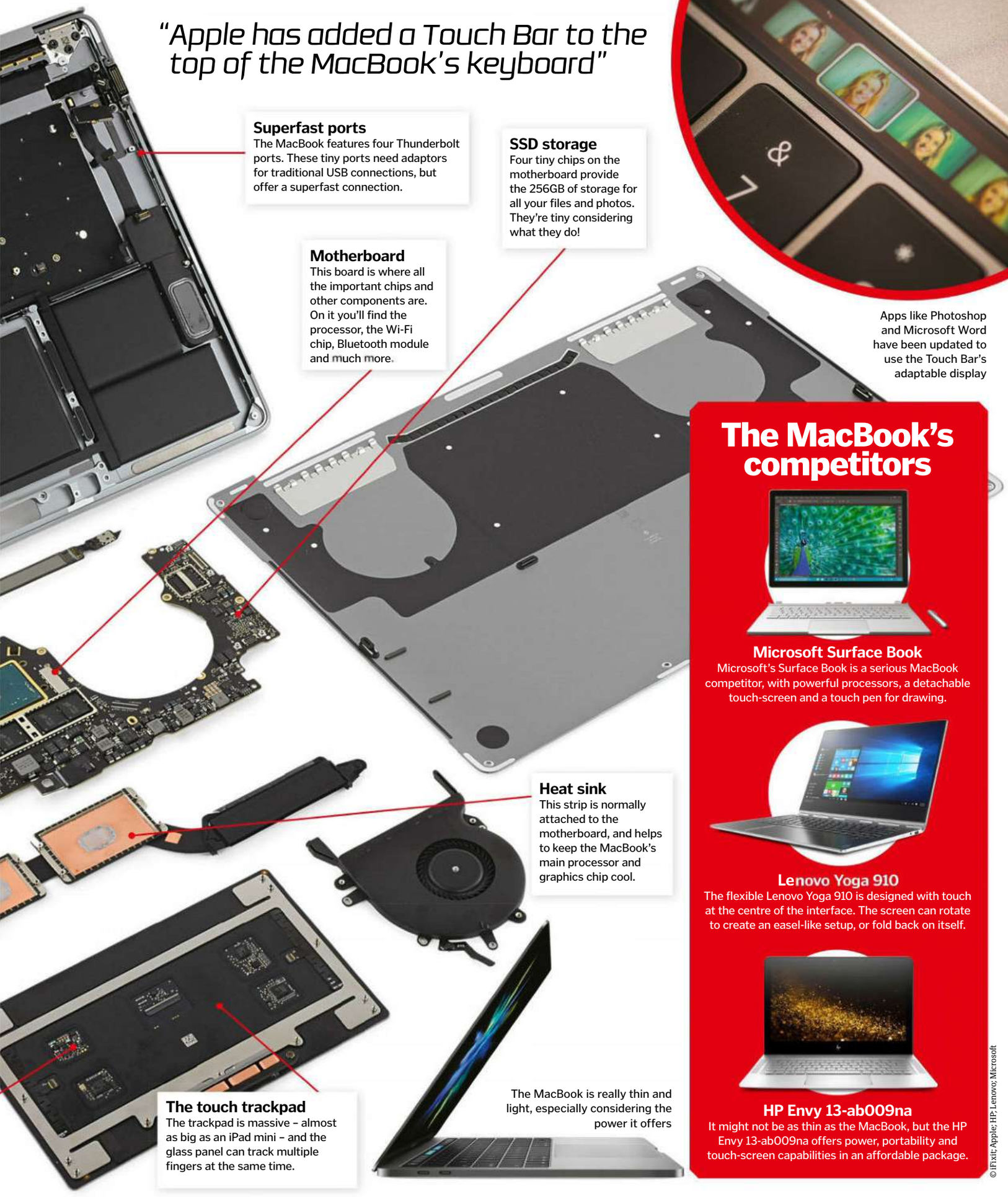
Speaker
There are two speakers, one on each side of the keyboard. These both pump out sound, so that the laptop can produce stereo audio.

Fans
The fans in Apple's laptops are very smart. The blades of the fans are all spaced out slightly differently, which means that when they spin the whirring sound is quieter.

The Touch Bar
This thin strip is the Touch Bar, a long touch-screen, which can change its display depending on what you're doing.

Haptic feedback
The small chips on the back of the trackpad control the touch-inputs, and also provide slight vibrations as feedback when you click.

"Apple has added a Touch Bar to the top of the MacBook's keyboard"



Superfast ports
The MacBook features four Thunderbolt ports. These tiny ports need adaptors for traditional USB connections, but offer a superfast connection.

SSD storage
Four tiny chips on the motherboard provide the 256GB of storage for all your files and photos. They're tiny considering what they do!

Motherboard
This board is where all the important chips and other components are. On it you'll find the processor, the Wi-Fi chip, Bluetooth module and much more.

Heat sink
This strip is normally attached to the motherboard, and helps to keep the MacBook's main processor and graphics chip cool.

The touch trackpad
The trackpad is massive – almost as big as an iPad mini – and the glass panel can track multiple fingers at the same time.

The MacBook is really thin and light, especially considering the power it offers

Apps like Photoshop and Microsoft Word have been updated to use the Touch Bar's adaptable display

The MacBook's competitors

Microsoft Surface Book
Microsoft's Surface Book is a serious MacBook competitor, with powerful processors, a detachable touch-screen and a touch pen for drawing.

Lenovo Yoga 910
The flexible Lenovo Yoga 910 is designed with touch at the centre of the interface. The screen can rotate to create an easel-like setup, or fold back on itself.

HP Envy 13-ab009na
It might not be as thin as the MacBook, but the HP Envy 13-ab009na offers power, portability and touch-screen capabilities in an affordable package.

Growing up among mine fields in Afghanistan inspired Massoud Hassani to design the drone

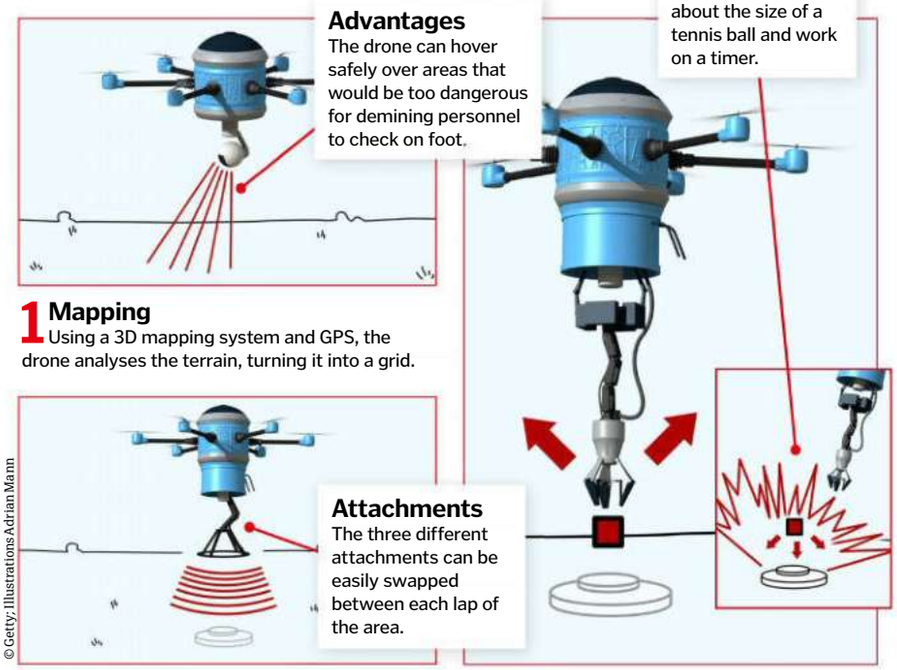
Minesweeper drones

The flying machine that can locate and destroy landmines quickly and safely

Ten people every day are killed or injured by landmines, left behind after conflicts and forgotten. There are thought to be 100 million worldwide, which will take hundreds of years to clear using current technologies. But one man hopes to do it in ten. Afghan designer Massoud Hassani has developed the Mine Kafon Drone, a flying robot that can map and destroy mines using its three different attachments. It is up to 20-times faster and 200-times cheaper than current methods, and more importantly keeps humans out of harm's way.

Search and destroy

The three-step mine removal process of the Mine Kafon Drone



1 Mapping
Using a 3D mapping system and GPS, the drone analyses the terrain, turning it into a grid.

2 Detecting
Hovering four centimetres above the mine, a metal detecting arm geotags its location.

3 Destroying
A robotic arm places a detonator on each mine, which is then triggered remotely.

File compression

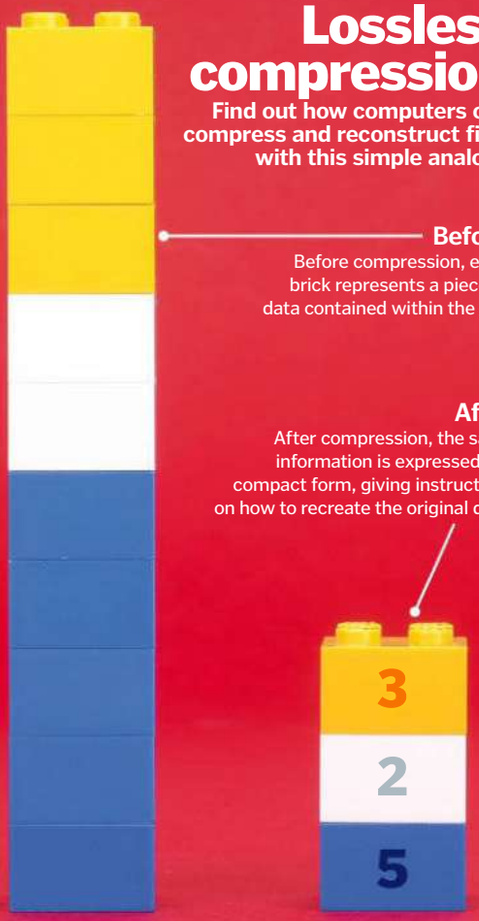
The clever process that makes it possible to share files online

Sending and downloading a complete image, audio or video file over the internet takes a long time, not to mention the fact that it eats up your bandwidth, so they are usually compressed first to make them more manageable. There are two main types of file compression, and the first, lossless compression, can be illustrated using bricks, as shown in this visual analogy. It works by replacing any redundant data, such as repeated information, with instructions telling the computer how to reconstruct the original file, and is typically used for text documents or image files intended for high-quality printing.

Lossy compression, on the other hand, simply removes the redundant information altogether, so the original file cannot be reconstructed. Audio files, for example, are commonly compressed this way into an MP3 format, with any sounds that humans can barely hear removed from the original recording. JPEG image files are also formed using this method, as they are intended to only be viewed on screen, not printed, and so a lot of the information can be removed. However, it's important to remember that lossy compression cannot be reversed.

Lossless compression

Find out how computers can compress and reconstruct files with this simple analogy



Vending machines

How these everyday devices dispense our favourite snacks and drinks

A vending machine has a simple premise: a customer inserts money and is given a product in return. The technology behind the machines, however, is much more complex.

The first vending machine was invented by ancient Greek engineer Hero of Alexandria, who created a coin-operated appliance that distributed holy water. These innovative creations would become popular much later in the 19th century, when vending machines in London were engineered to sell postcards.

A keypad is now a common way of choosing your preferred confectionary, but some of today's vending machines use touchscreen technology instead. This gives the user more information about the product they are ordering when they part with their hard-earned cash.

Some vending machines also have microchips that scan your smartphone to complete the transaction. The latest devices even have facial recognition built in so it can remember your past orders if you're a frequent user. Some can also save energy by only cooling popular items, or only cooling during certain periods of the day. Airtight doors prevent the cool air from being lost, keeping the products nicely chilled.

Modern vending machines can stock all kinds of items, including burgers, shoes and even gold ingots

A vending machine doesn't simply sell just snacks anymore, and can provide almost everything from hamburgers to prescription medicine. There are even 3D printer vending machines designed to print out 3D models when an SD card is inserted.

Forgeries and fakes

When banknotes or coins are inserted, a vending machine has to identify their value and whether they are legal tender or not. Notes move along a small treadmill and travel underneath an optical scanner, which can process the image for signatures of legitimate currency. Some notes are also printed with fluorescent or magnetic ink, which a scanner can also recognise.

Simpler vending machines judge coins by measurements such as thickness, diameter and the number of ridges, but more advanced machines can use electromagnetism to identify different coins. Unaccepted or damaged notes are simply fed back to the customer, while fake or unreadable coins are dropped straight into the dispenser where change is given.

Some banknotes contain ink that fluoresces when exposed to a specific light in vending machines

Inside a vending machine

How these machines collect your cash and deliver your chosen product

Pay by card

For those short of cash, many vending machines now accept payment from credit cards, contactless debit cards and smartphones.

Coin mechanism

An electromagnetic field can judge the authenticity of coins, identifying what value they are and if they are the correct currency.

Metal spirals

Products are held in place by spiral rings. A motor is controlled by the computer, which turns the coils when that product is chosen and the correct amount of money is inserted.

Dispenser

A line of lasers and light sensors at the bottom of the dispenser let the computer know if the customer has received their product or not.

Central computer

The vending machine's computer is located behind the keypad and reads which combination the customer has punched in.

Detecting the fakes

Some machines assess the composition of coins from their thickness to the amount of ridges they have.

CASSINI-HUYGENS' GRAND FINALE

How this groundbreaking mission revealed the secrets of Saturn

Cassini-Huygens is arguably the greatest mission humanity has ever sent into the cosmos. It has almost single-handedly revolutionised our knowledge of Saturn and its moons, providing vital clues in the search for life beyond Earth in the process.

On 15 October 1997, Cassini-Huygens was lofted into space aboard a Titan IV-B rocket from Cape Canaveral in Florida. The primary spacecraft, NASA's Cassini, was named after the 17th century Italian-French astronomer Giovanni Domenico Cassini, who discovered gaps in Saturn's rings and four of its moons. Its companion, a small spacecraft built by the European Space Agency (ESA) named Huygens, which would attempt a daring landing on the moon Titan, was named for that moon's discoverer, Dutch astronomer Christiaan Huygens, also from the 17th century.

Prior to Cassini, only three spacecraft had ever glimpsed Saturn up close. The first was Pioneer 11 in September 1979, which flew within 20,000 kilometres of the planet. It was followed by Voyager 1 in November 1980, and Voyager 2 in August 1981, both also flying past the gas giant. But no spacecraft had ever orbited Saturn.

That all changed on 1 July 2004, when Cassini officially entered orbit to rapturous applause in mission control following a journey of 3.5 billion kilometres. On 24 December that year, it released the Huygens probe. Entering the atmosphere of Titan on 14 January 2005, Huygens took measurements of Titan's wind, atmosphere and more all the way to the surface, where it returned images before succumbing to the harsh environment. To this day, it remains the only landing in the outer Solar System.

Cassini's mission has been extended twice, during which time it has discovered bodies of liquid on Titan, jets of possible water spurting from Enceladus, irregularities in Saturn's rings caused by small moonlets, and much more.

This year, however, we will be saying goodbye to the Cassini mission. On 15 September 2017, the spacecraft will be sent to burn up in the atmosphere of Saturn as it's running out of fuel. Right up to its very last moments, though, it will be returning stunning data to Earth.

WHAT WE'VE LEARNED ABOUT SATURN

Some of the stunning discoveries Cassini has made in its 13 years of operations

In 2010, Cassini was on hand to witness a remarkable storm encircle the entire planet of Saturn. It lasted for about a year and in the process shot plumes of gas high into the atmosphere of the planet. It also produced a 5,000-kilometre-wide vortex, sent jet streams across the planet and disrupted Saturn's seasons. These planet-wide storms repeat roughly every 20 to 30 years, possibly kept quiet in between by vapour in Saturn's atmosphere.

Studying the rings of Saturn, Cassini has managed to glimpse how Saturn formed its 62 known moons. In 2013, it spotted an object at the outer edge of the rings that is thought to have grown within them, which will move away from the rings and eventually become a fully-fledged satellite. It also found giant vertical mounds of icy particles in the rings that towered up to four kilometres high.

Cassini has observed dramatic seasonal changes in the atmosphere of Saturn, brought about by its long 30-year orbit around the Sun and the cooling effect of the shadow caused by its rings. The planet is able to quickly adjust to any changes of temperature by filling cold areas with warmer air.

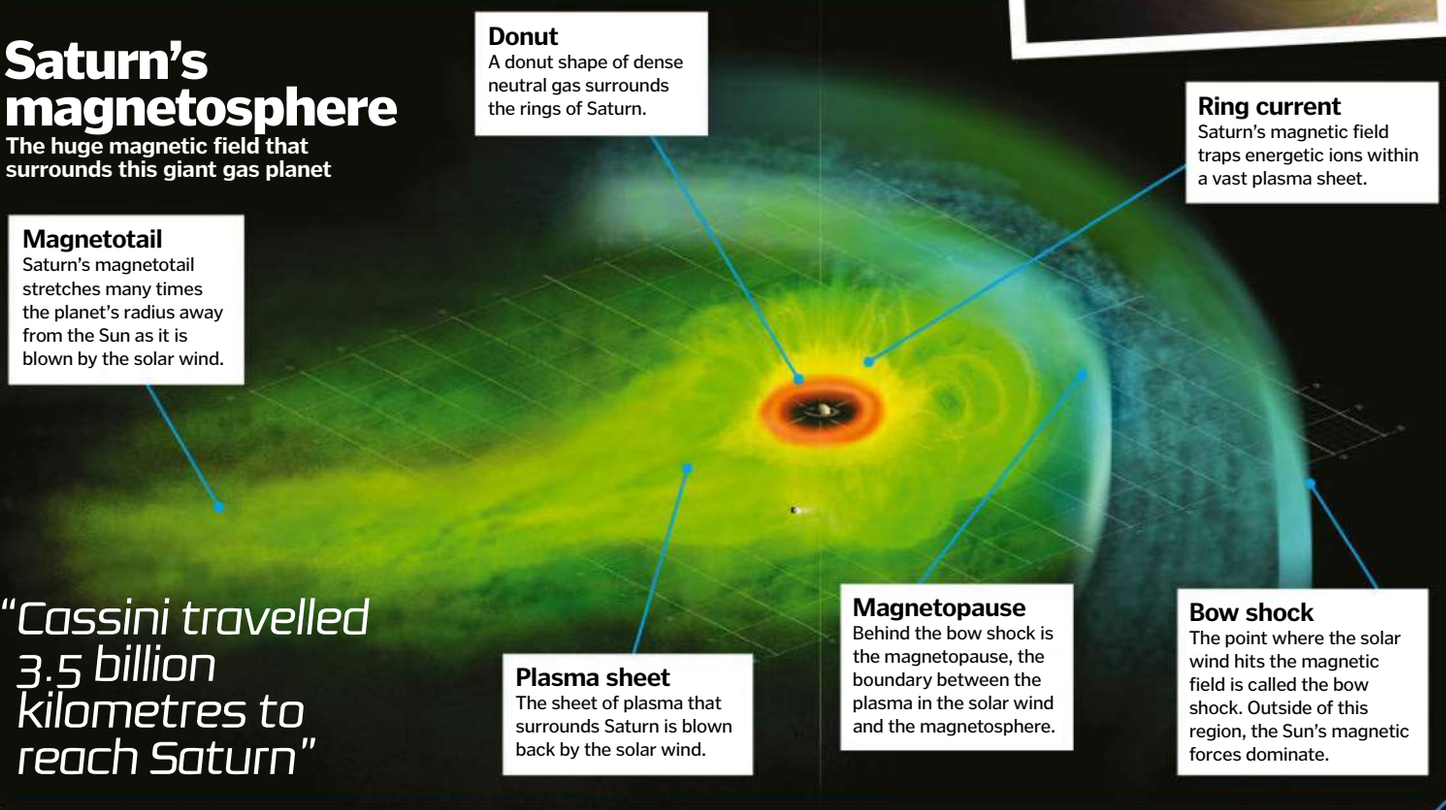
One particularly surprising finding was a large and long-lived hexagonal jet stream in the north pole, and two hurricane-like storms in the south. The eye of the northern storm is about 50-times larger than an average hurricane on Earth, although how these storms form is not entirely clear.

Cassini also made an interesting discovery about Saturn's magnetosphere, namely that it is fed by the moon Enceladus, although it is generated deep in the planet's fluid interior. Saturn's magnetic field is much weaker than Jupiter's, but was thought to be linked to the rotation rate of Saturn. However, despite measurements from Cassini, scientists still aren't sure exactly how fast Saturn rotates – anywhere from about 10.6 to 10.8 hours. It may be that something in Saturn's atmosphere is disrupting the effects of the planet's magnetic field, and scientists hope to get a better idea as Cassini gets closer to Saturn this year.

Saturn has a mysterious hexagonal jet stream at its north pole

Saturn's magnetosphere

The huge magnetic field that surrounds this giant gas planet



Donut
A donut shape of dense neutral gas surrounds the rings of Saturn.

Ring current
Saturn's magnetic field traps energetic ions within a vast plasma sheet.

Magnetotail
Saturn's magnetotail stretches many times the planet's radius away from the Sun as it is blown by the solar wind.

Plasma sheet
The sheet of plasma that surrounds Saturn is blown back by the solar wind.

Magnetopause
Behind the bow shock is the magnetopause, the boundary between the plasma in the solar wind and the magnetosphere.

Bow shock
The point where the solar wind hits the magnetic field is called the bow shock. Outside of this region, the Sun's magnetic forces dominate.

"Cassini travelled 3.5 billion kilometres to reach Saturn"

WHAT WE'VE LEARNED ABOUT SATURN'S MOONS

Cassini's major discoveries regarding Saturn's 62 known moons

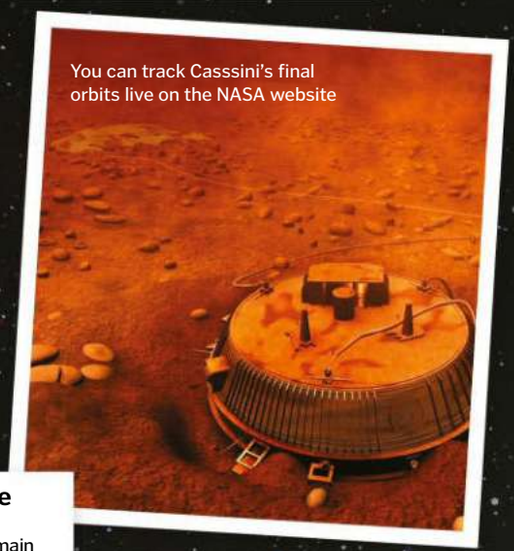
Saturn's moon Hyperion has a weird, sponge-like appearance

One of Cassini's earliest discoveries concerned Titan. The atmosphere of this moon is so thick that we cannot see through it from Earth, but by bouncing radio waves off the ground, Cassini has painted a picture of what it looks like. Together with the Huygens lander, it found evidence of organics in the atmosphere and on the surface of Titan, which are the building blocks of life. Using its radar, it has also identified lakes and seas on the surface, composed of liquid hydrocarbons. This makes Titan the only place other than Earth known to have bodies of liquid on its surface.

Cassini returned stunning images of the bizarre two-toned moon called Iapetus, one side of which is as black as tar, and the other as bright as snow. It was first theorised to have two colours back in the 17th century by Giovanni Cassini, but it was not until his namesake probe arrived that we got to look close-up. Thanks to the spacecraft, we now believe that the dark material is caused by dust from other moons hitting Iapetus, coupled with ice migrating to the poles.

Perhaps the most surprising discovery of all though were plumes of liquid ejecting from the south pole of the moon Enceladus. Further studies led to the prediction that Enceladus must have a vast ocean of water beneath its surface, which may provide a habitable environment for life. Hot spots from the ocean cause the jets to escape, and Cassini has flown through them a couple of times to sample them. The moon appears to be geologically active, with 'tiger stripes', or cracks, running across its surface.

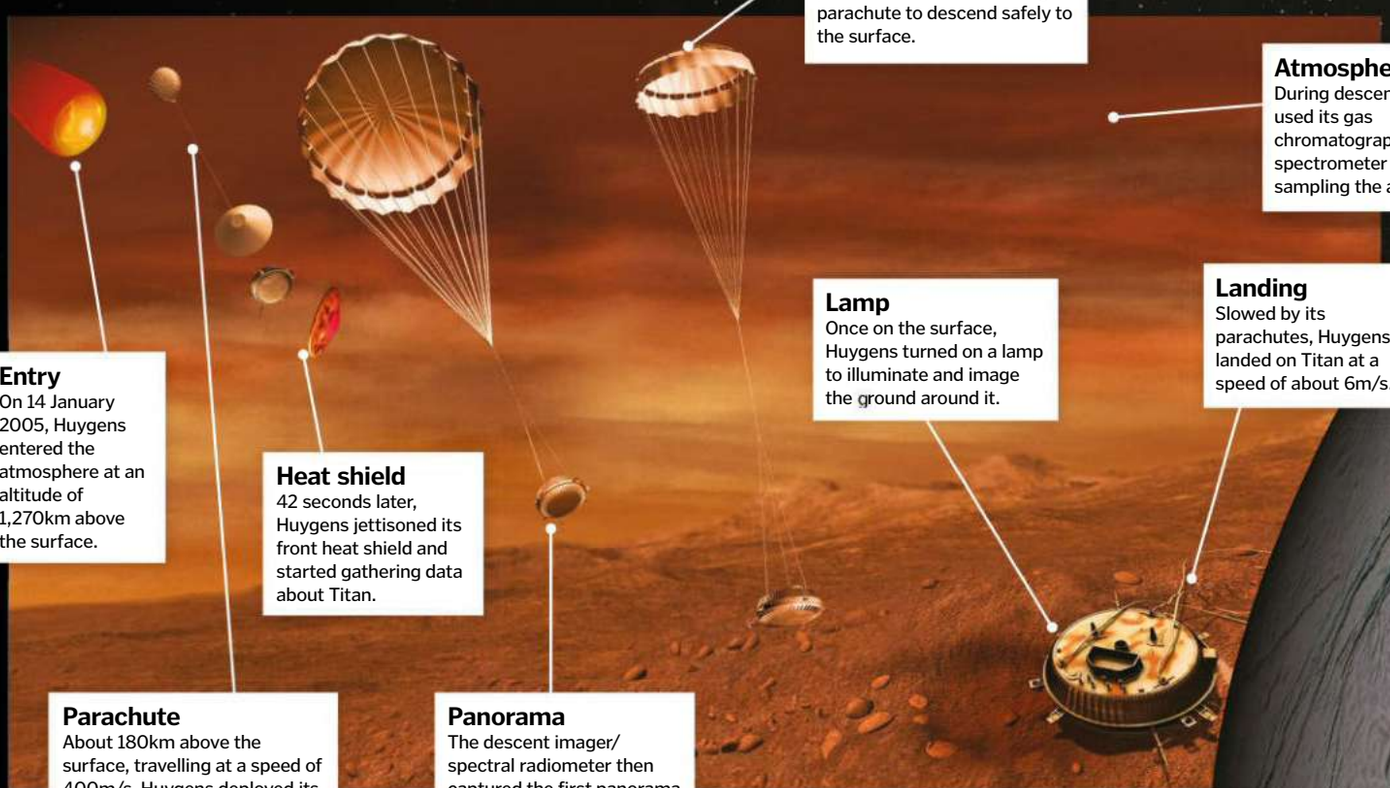
Cassini has also provided fascinating information on a number of other Saturnian moons. It discovered that the sponge-like moon Hyperion builds up a static charge, the only moon other than Earth's known to do so. Dione and Rhea, meanwhile, were found to have extremely thin atmospheres, about 5 trillion times less dense than the atmosphere at ground level on Earth. Mimas, nicknamed the Death Star moon for the large defining crater on its surface, may have a small underground ocean like Enceladus. Cassini also found several more small moons hiding in Saturn's rings.



You can track Casssini's final orbits live on the NASA website

Huygens on Titan

How this probe performed the first landing in the outer Solar System



Drogue parachute
At an altitude of 125km, Huygens jettisoned its main parachute and used its drogue parachute to descend safely to the surface.

Atmosphere
During descent, Huygens used its gas chromatograph and mass spectrometer to start sampling the atmosphere.

Lamp
Once on the surface, Huygens turned on a lamp to illuminate and image the ground around it.

Landing
Slowed by its parachutes, Huygens landed on Titan at a speed of about 6m/s.

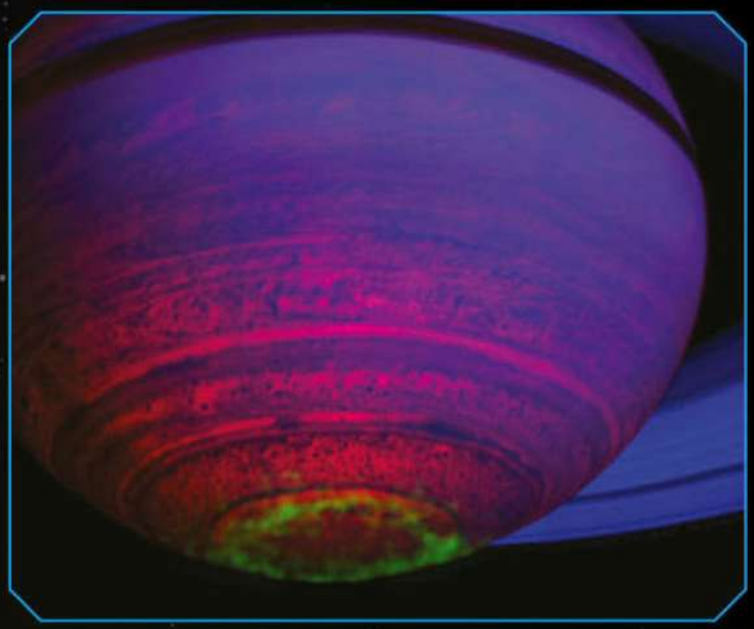
Entry
On 14 January 2005, Huygens entered the atmosphere at an altitude of 1,270km above the surface.

Heat shield
42 seconds later, Huygens jettisoned its front heat shield and started gathering data about Titan.

Parachute
About 180km above the surface, travelling at a speed of 400m/s, Huygens deployed its pilot parachute, followed by its main parachute.

Panorama
The descent imager/ spectral radiometer then captured the first panorama of Titan, and took images all the way down.

This Great White Spot storm was seen encircling Saturn in 2011



Saturn's magnetic field can create powerful aurorae at its poles

Enceladus' ocean

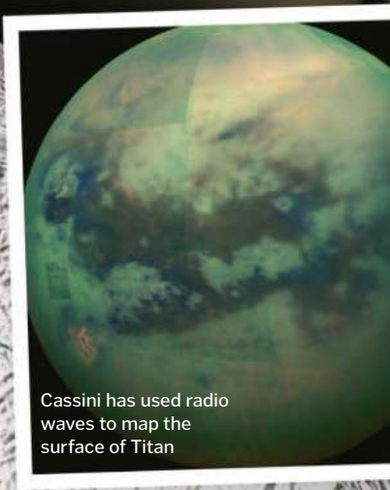
Cassini revealed this moon has a vast amount of water under its icy surface

Ice shell
The icy surface of Enceladus is thought to be about 30 to 40km thick.

Plumes
Jets of material from the ocean shoot out at about 1,300km/h and extend hundreds of kilometres into space.

Hot spots
The plumes may be the result of hotspots or hydrothermal vents blasting material up through cracks in the surface.

Ocean
Beneath the icy shell, the ocean may be as thick as 10km based on gravity data from Cassini.



Cassini has used radio waves to map the surface of Titan

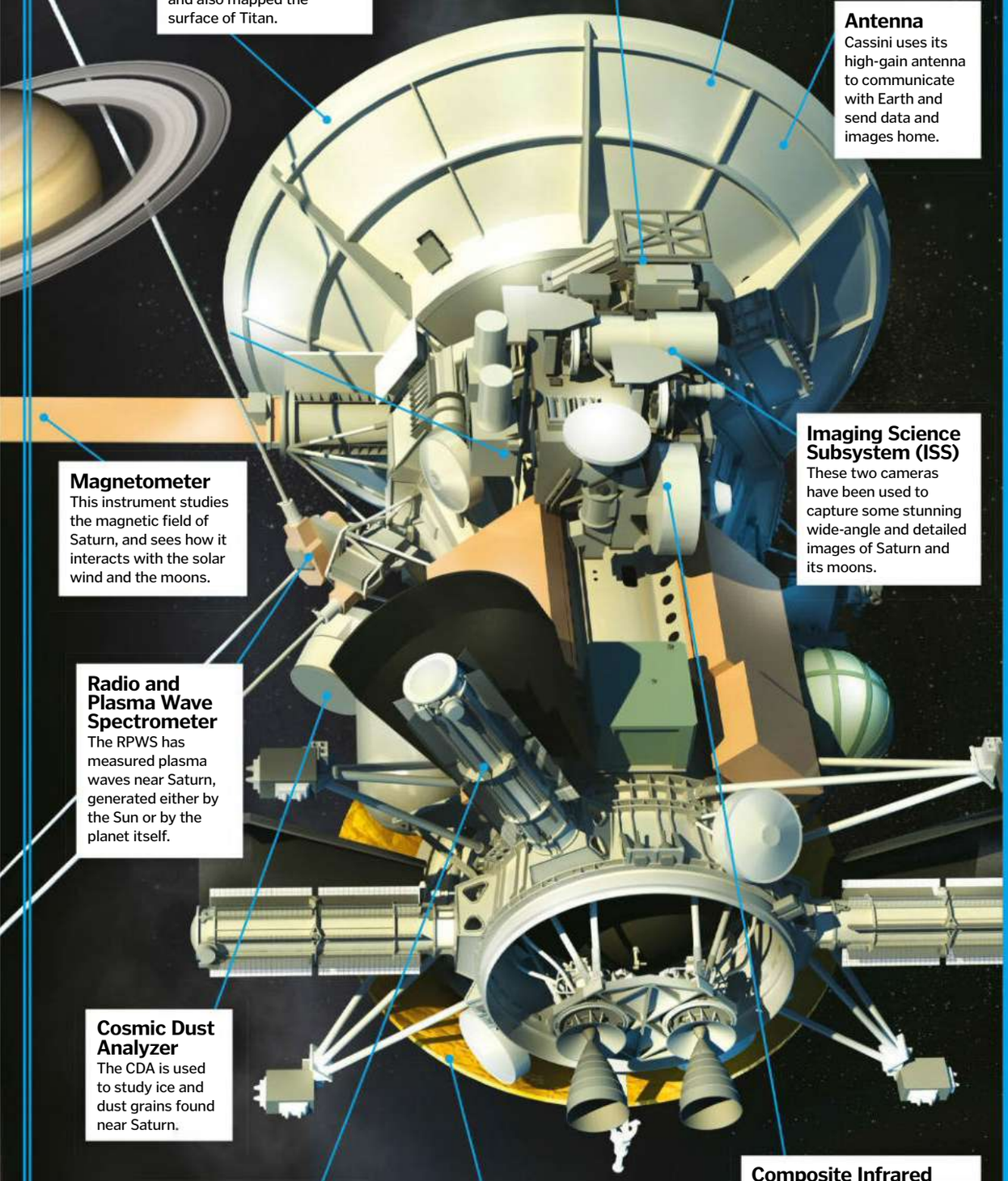
Rocky core
At the bottom of the ocean is the rocky core of Enceladus, which may be heated by being pushed and pulled by Saturn's gravity during its orbit.

"Perhaps the most surprising discovery of all were plumes of liquid ejecting from Enceladus"

Tiger stripes
Cracks on the surface known as tiger stripes may be the result of the hot water interacting with the icy shell.

Inside Cassini

The instruments that have helped this spacecraft explore Saturn



Radar
The Cassini radar uses radio waves to map the height of surface features on moons, and also mapped the surface of Titan.

Visible and Infrared Mapping Spectrometer
The VIMS has been used to measure the chemical compositions of the surfaces and atmospheres of the rings and moons of Saturn.

Radio Science Subsystem
Interestingly, the RSS was intended to find gravitational waves beyond the Solar System, but has found none so far.

Antenna
Cassini uses its high-gain antenna to communicate with Earth and send data and images home.

Magnetometer
This instrument studies the magnetic field of Saturn, and sees how it interacts with the solar wind and the moons.

Imaging Science Subsystem (ISS)
These two cameras have been used to capture some stunning wide-angle and detailed images of Saturn and its moons.

Radio and Plasma Wave Spectrometer
The RPWS has measured plasma waves near Saturn, generated either by the Sun or by the planet itself.

Cosmic Dust Analyzer
The CDA is used to study ice and dust grains found near Saturn.

RTGs
The spacecraft has three Radioisotope Thermoelectric Generators (RTGs) to supply it with power.

Huygens probe
The ESA's Huygens probe detached from Cassini on 24 December 2004. It successfully coasted to Titan and landed 21 days later.

Composite Infrared Spectrometer
The CIRS is used to measure infrared energy from the surface and atmospheres of the moons, and from Saturn's rings and its atmosphere.

Cassini by numbers

Stats and facts about this pioneering spacecraft

7 YEARS
How long it took for Cassini to reach Saturn

3.5BN KM
The distance Cassini travelled to reach Saturn

85 MINS
It takes nearly 1.5 hours to send or receive a signal from Cassini

10
Number of new moons found by Cassini

$3.27 BILLION
The total cost of the Cassini space mission

379,300
Cassini has taken almost 400,000 images as of 2016

27
Number of nations involved in the mission

3,616
Science papers published on Cassini data as of 2016

THE FINAL MISSION

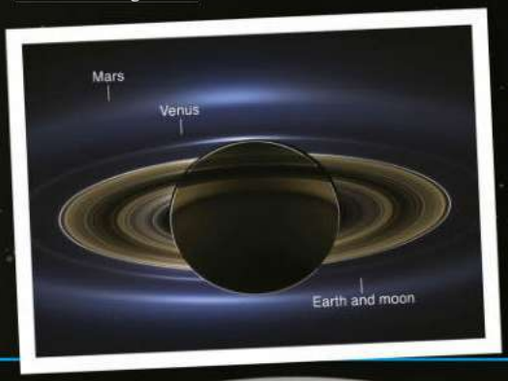
Soon we'll be saying goodbye to the Cassini spacecraft

They say all good things must end. For this mission, it may be one of the most bittersweet endings of all. On 15 September 2017, Cassini will be purposefully sent into the atmosphere of Saturn to destroy the spacecraft as it begins to run out of fuel. It will have spent almost 20 years in space, and returned a huge amount of scientific data in the process.

Starting on 22 April, Cassini will begin a series of 22 orbits that take it between the planet and the inner edge of the rings, each taking six days. These orbits will give Cassini a closer look at Saturn than ever before, with some of the science including studying the interior of the planet, measuring the amount of material in the rings and even sampling them. We'll also, of course, be getting some rather stunning images of Saturn's rings and the planet itself up close. It will be the closest any spacecraft has ever come to the gas giant. Prior to this, Cassini is performing a series of ring-grazing orbits, where it is passing through the outer edges of the rings. It began these in December 2016 and is continuing up until the grand finale begins. In both phases, there will be multiple flybys of some of the moons too, including Titan, so expect some more images.

One of the major reasons for ending the spacecraft with its destruction is to prevent it from contaminating one of the moons like Titan or Enceladus with Earth-based microbes, as the two may be potentially habitable. This has been done with spacecraft before to prevent similar situations occurring, such as the Galileo spacecraft around Jupiter in 2003.

There will be some glorious science and images all the way down but, sadly, later this year we will be saying goodbye to what has been a truly groundbreaking mission. This will leave Saturn without a spacecraft in orbit for the first time since 2004, and at the moment it's not quite clear when we'll be returning. But the Cassini won't be forgotten.

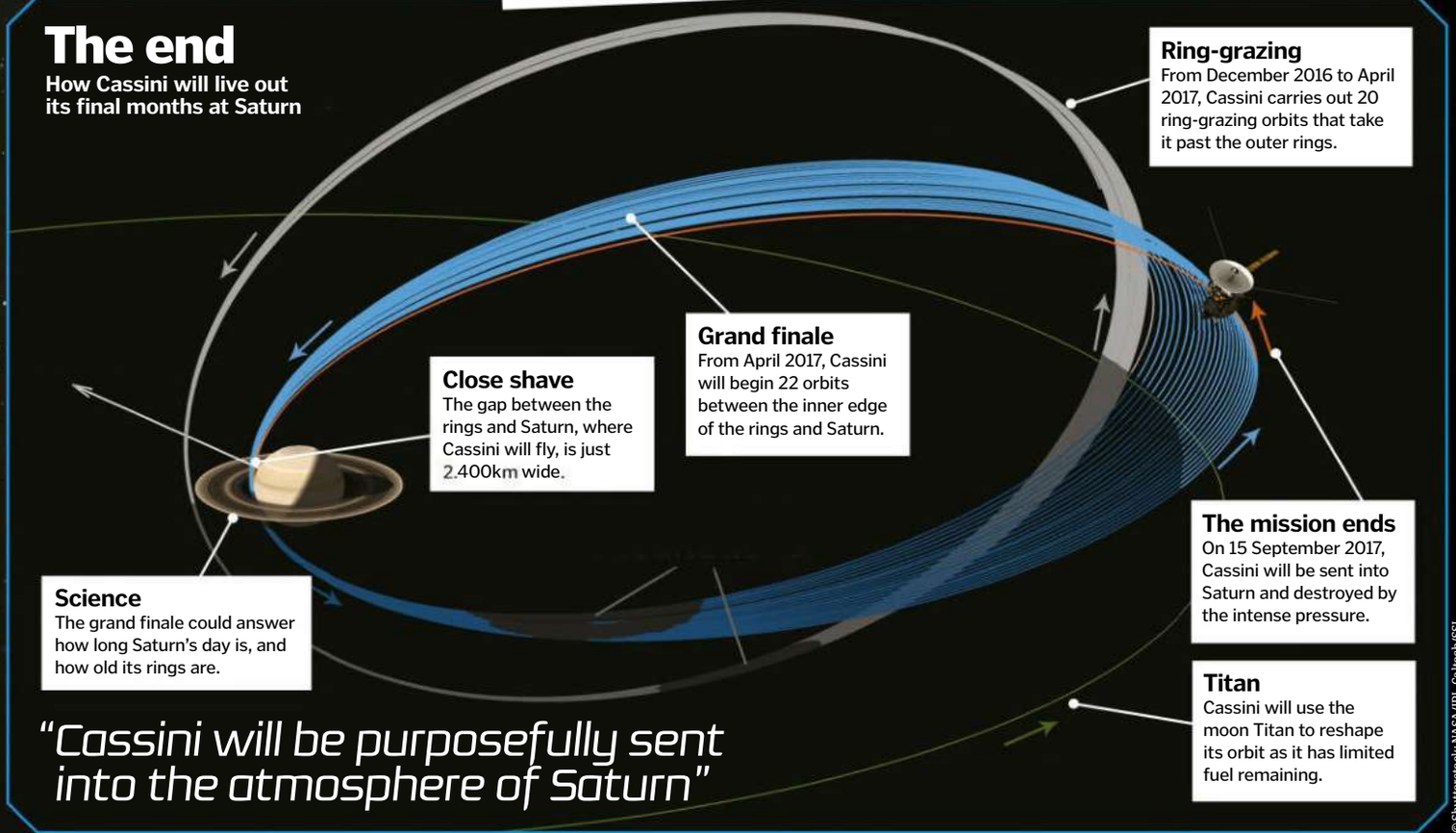


ABOVE Scientists work to assemble the Cassini spacecraft

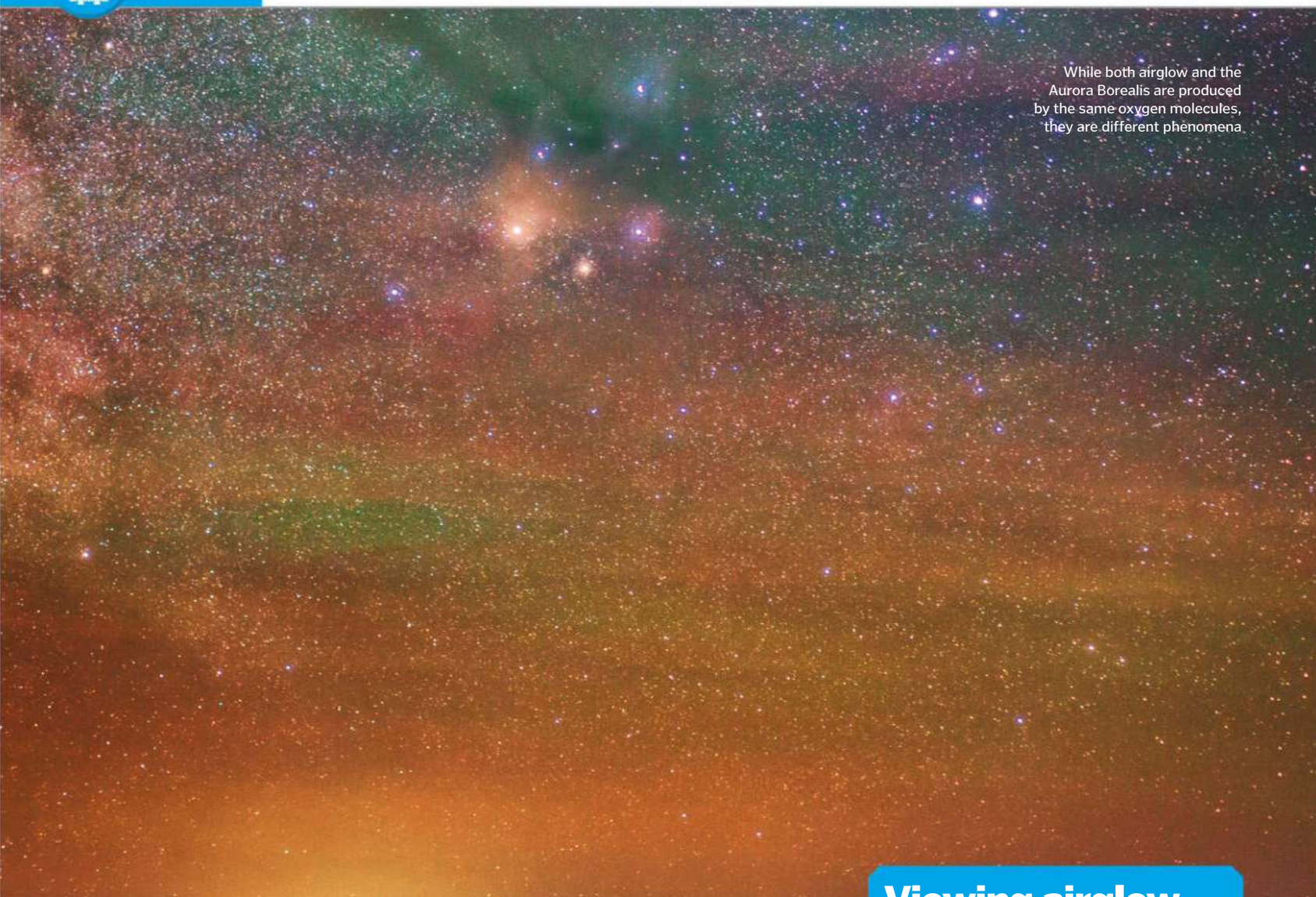
BELOW Cassini's demise will bring to an end 13 years of exploration at Saturn

The end

How Cassini will live out its final months at Saturn



"Cassini will be purposefully sent into the atmosphere of Saturn"



While both airglow and the Aurora Borealis are produced by the same oxygen molecules, they are different phenomena

Airglow

The science behind the phenomena that causes the sky to glow in a rainbow of colours

Airglow is a photochemical reaction in the Earth's atmosphere caused by electronically excited atoms, molecules and ions that react to ultraviolet radiation from the Sun. When these components return to their normal state, they release energy in the form of visible and infrared light. What we see as a result of this is usually a green glow.

Although the glow is present at all layers of the atmosphere, it's only visible across a narrow band that is six to ten kilometres wide and around 85 to 95 kilometres high into the atmosphere. Below 85 kilometres, the atoms and molecules collide more readily as they're more concentrated, so their energy is released sooner. Above 95 kilometres, the atmosphere's density is too low for the atoms to collide enough.

The three types of airglow – dayglow, twilightglow and nightglow – all form in different ways. Dayglow is produced when molecules in the daylight atmosphere absorb sunlight and gain excess energy. As they become excited they release the energy as light at the same or a slightly lower frequency as the light they absorbed, but we can't see it because it is much dimmer than daylight.

The difference with twilightglow is that only the upper atmosphere is lit by the Sun, so the light is visible to the naked eye because we and the rest of the atmosphere are in darkness. Since no sunlight shines on the nighttime atmosphere, nightglow is very different. As such, chemiluninescence is responsible for the glowing atmosphere after dark.

Viewing airglow

The best way to view airglow is from the International Space Station (ISS) when it is orbiting over the night side of Earth. From here, airglow will look like a thin band because the ISS is viewing the atmosphere at a shallow angle, so the airglow layer's relative visibility is therefore increased.

However, most of us don't have access to the ISS, so how do we increase our chances of catching a glimpse of this phenomenon? The most effective way is to take a long-exposure photograph of a clear, dark night sky. As long as you aim your camera around ten to 20 degrees above the horizon at an area of sky that is free from light pollution, you should be able to capture airglow.

To try and capture this atmospheric spectacle, take a long-exposure photo of a clear night sky

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Space-based solar power

Can we feasibly beam solar energy to Earth from space?

The idea of space-based solar power (SBSP) goes back to the mid-20th century, touted as a way to provide us with vast amounts of clean energy from space. Despite the promise of a better future, though, the technology has largely struggled to get off the ground.

Solar panels on Earth are hampered by our atmosphere, which blocks about 30 per cent of the energy from sunlight reaching our planet. In space, however, solar panels have an unobstructed view of the Sun's rays.

SBSP would see satellites laden with solar cells placed high in orbit – perhaps geostationary orbit about 35,800 kilometres up – where they can stay over the same spot on Earth. Reflectors would be used to direct solar radiation onto solar panels, with the solar power converted into a microwave or laser and beamed back to collectors on Earth. Positioned here, a satellite can be in almost continuous sight of the Sun.

Some estimates suggest solar cells in space could outperform their Earth-based counterparts by 40 times. But in order to power anything as large as a city you'd need enough reflectors to span about three kilometres in space, with a similarly sized collector on Earth.

Several organisations have looked into the feasibility of SBSP, including NASA and the Japanese space agency, JAXA. But there are a number of issues, not least the cost of launching and assembling the satellites, and working out how to efficiently beam the power back to Earth. It's an exciting idea that sounds like science fiction. For now, it may remain just that.

Beaming to Earth

How to collect solar energy and send it down from space

Receiver
A receiving station on Earth, perhaps wires spread over a field, would harness the incoming beamed energy.

Beam
Either a microwave or laser beam would be used to send the solar energy to Earth.

Geostationary
In a geostationary orbit 35,800km up, the satellite would always be above the same location on the equator of Earth.

Drawbacks

Despite the exciting potential of space-based solar power, there's a reason we're not living off it yet. For one thing, launching the large satellites required to collect this energy is hugely expensive. Estimates suggest a system to power a city with SBSP would cost in the tens of billions of dollars.

Then there's the issue of transmitting the energy to Earth. Our best microwave transmitters can only manage a few hundred meters so far, while laser transmission, although able to handle the distance, wouldn't carry enough energy to be useful.

SBSP certainly has its proponents. But other options like nuclear fusion might be more viable for our future energy needs.

Launch costs in to space are still in the tens of millions of dollars

Array
An array could be used to direct the beam on Earth, so that the satellite can stay in the same position.

Reflector
Mirrors could be used to bounce solar radiation into the cells and keep the satellite in one position.

"SBSP would see satellites laden with solar cells placed high in orbit"

Transmitter
Microwave or laser-based wireless power transmission could be used to send the energy to Earth.

Converter
Photovoltaic cells could be used to convert the incoming solar radiation into a transmittable form of energy.

Solar cells
Solar panels on the satellite would collect the incoming solar radiation.

Solar energy

In one second, our Sun produces as much energy as humankind has used in its entire history. While this radiates in all directions, what hits us here on Earth still amounts to a lot. At any one time we receive about 173,000 terawatts (trillions of watts) of energy, which is about 10,000 times more than our total energy use at any one time. Almost a third of this gets blocked by our atmosphere, and considering that 71 per cent of our planet is water, we can't collect it all. But there's a vast amount of energy there for us to harness, if we want it.

The Sun's energy could power all our electronics on Earth with ease

Dark matter and dark energy

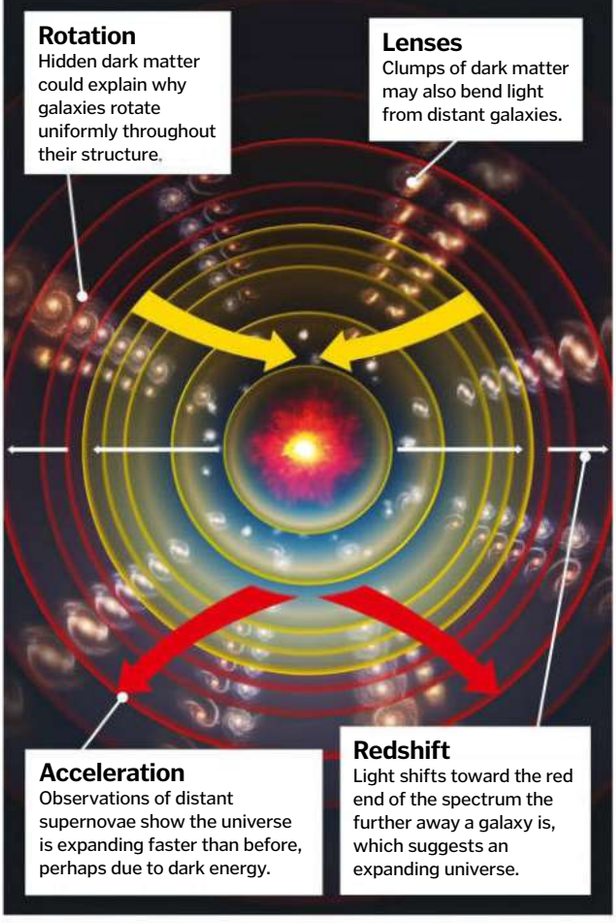
There's still much we don't know about our universe

Despite their similar names, dark energy and dark matter are separate – but they are equally mysterious. Dark energy is thought to be a force that causes the expansion of the universe to accelerate. In theory, gravity should cause the universe to decelerate and collapse, but that's not the case. Dark energy is thought to make up 68 per cent of the universe and permeates through all of space. The only problem is we have no direct evidence for its existence – but many think it's a viable possibility.

Dark matter, on the other hand, is a type of unseen matter that we have indirect evidence for. Making up 27 per cent of the cosmos, we can predict it's there based on the way galaxies rotate. Their outer stars travel just as fast as their inner stars, suggesting invisible halos of matter – dark matter – may be lurking at their edges.

The evidence

Why we think dark energy and dark matter exist



Rotation
Hidden dark matter could explain why galaxies rotate uniformly throughout their structure.

Lenses
Clumps of dark matter may also bend light from distant galaxies.

Acceleration
Observations of distant supernovae show the universe is expanding faster than before, perhaps due to dark energy.

Redshift
Light shifts toward the red end of the spectrum the further away a galaxy is, which suggests an expanding universe.

The future of the Solar System

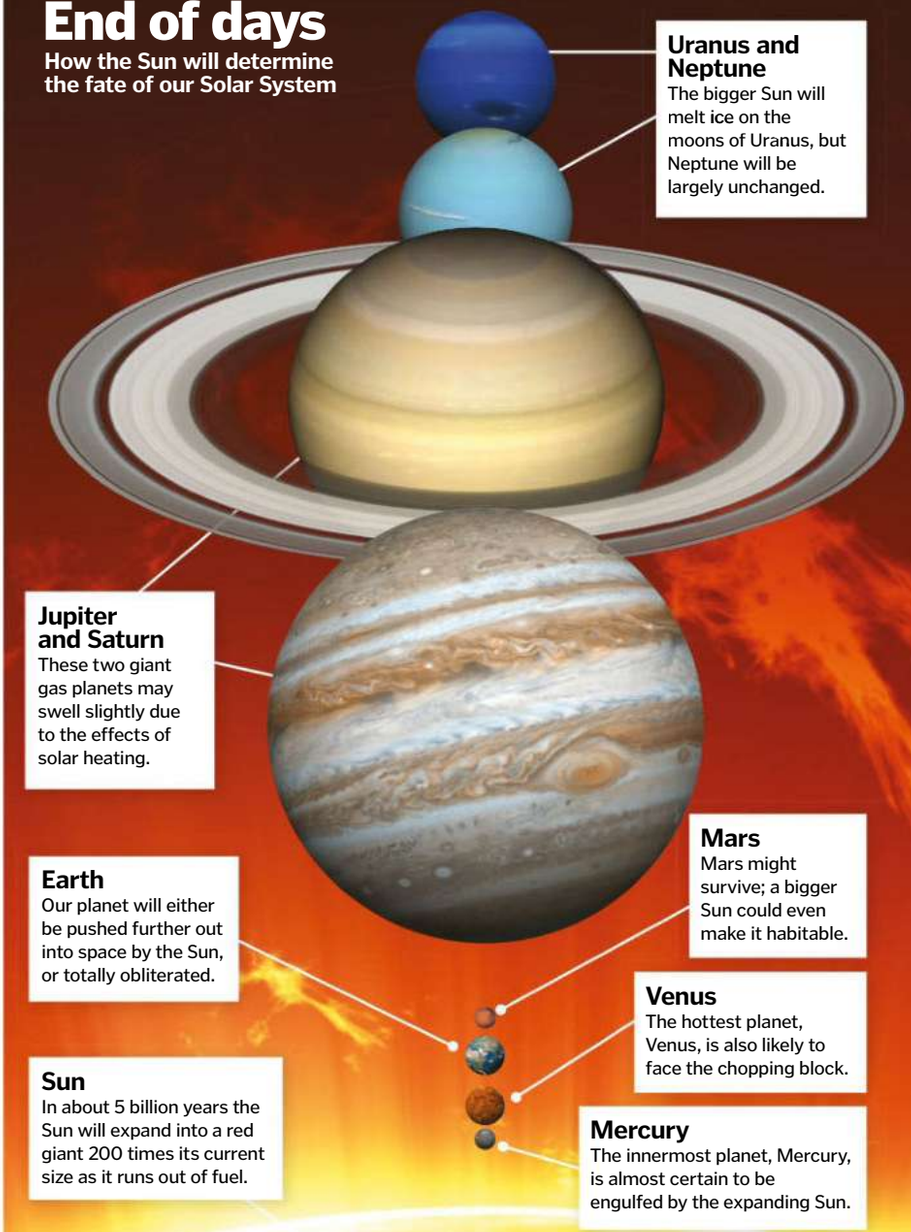
What will become of the Sun and the planets in a few billion years?

At 4.6 billion years old, our Sun is about halfway through its lifetime. But, eventually, it will run out of fuel, and that might not be good news for us.

As our Sun ages, it fuses its hydrogen into helium in a process called nuclear fusion. Once the hydrogen is gone, it will start fusing heavier and heavier elements, causing the star to expand as its internal pressure builds. It will continue expanding into a red giant, eventually becoming so big that it swallows Mercury and Venus as it grows to about twice the Earth-Sun distance. And it could consume us too, unless we get pushed out further. But the Sun will boil our oceans away about one or two billion years from now as it gets hotter, so don't worry too much.

End of days

How the Sun will determine the fate of our Solar System



Uranus and Neptune
The bigger Sun will melt ice on the moons of Uranus, but Neptune will be largely unchanged.

Jupiter and Saturn
These two giant gas planets may swell slightly due to the effects of solar heating.

Earth
Our planet will either be pushed further out into space by the Sun, or totally obliterated.

Mars
Mars might survive; a bigger Sun could even make it habitable.

Venus
The hottest planet, Venus, is also likely to face the chopping block.

Sun
In about 5 billion years the Sun will expand into a red giant 200 times its current size as it runs out of fuel.

Mercury
The innermost planet, Mercury, is almost certain to be engulfed by the expanding Sun.

What are dwarf planets?

How these diminutive worlds differ from their more expansive counterparts

As their name suggests, dwarf planets share a lot of similarities with what we would generally refer to as 'planets'. For instance, they orbit the Sun, and possess enough mass to assume an approximate spherical shape. However, it is their differences that serve to draw a dividing line between them and what astronomers consider to be true planets.

The most apparent observation is that dwarf planets are much smaller than conventional planets; even smaller than the size of Earth's Moon (although they can have moons themselves). Their size also means that they are unable to clear their orbital path, as is the case with Pluto, which is restricted by both the orbit of its larger neighbour Neptune and assorted objects in the Kuiper Belt. The planets of the Solar System are able to clear a path around the Sun for their orbit, while dwarf planets are unable to do this.

Currently, there are five recognised dwarf planets in our Solar System: Ceres, Eris, Makemake, Haumea and Pluto, which was controversially reclassified in 2006, having originally been recognised as the ninth planet in the Solar System. Distinguishing them even further is the International Astronomical Union's (IAU) designation of dwarf planets that orbit the Sun beyond Neptune as 'plutoids', in honour of the former planet.

NASA's Dawn spacecraft recently found evidence of organic material on Ceres, indicated by the red areas on the image

The big planets' little siblings

Meet the five celestial dwarves of our Solar System that have been discovered so far

Ceres

Ceres is located in the main asteroid belt between Mars and Jupiter, and was first discovered in 1801. It is described as an 'embryonic planet' due to the gravitational pull from nearby Jupiter preventing it from gaining the mass required to complete its growth.

Pluto

Originally designated as the ninth planet in the Solar System, Pluto was reclassified – controversially according to some – as a dwarf planet in 2006 due to its failing to meet the added criteria of being able to clear its own orbital path. In spite of its size, Pluto has five moons: Charon, Hydra, Nix, Kerberos and Styx.

Eris

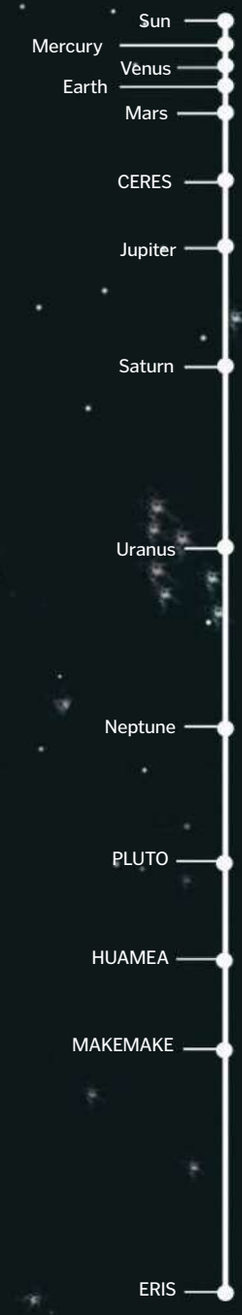
Named after the Greek goddess of discord and strife, the climate on Eris is aptly turbulent. Due to its distance from the Sun, its atmosphere often collapses and subsequently freezes. Moreover, its orbit is similarly erratic, crossing the path of Pluto and nearly intersecting with Neptune's on an orbit of the Sun that takes Eris 557 years.

Makemake

Discovered in 2005, it was Makemake – along with the uncovering of Eris two years before – that prompted the IAU to reconsider the classification of planets in the first place. This dwarf planet takes its name from the god of fertility in Rapanui mythology, which originated with the native people of Easter Island.

Haumea

Haumea's ellipsoid shape means that it only just meets dwarf planet criteria. Its unusual shape is due to the rapid rotational spin that it possesses. It is thought that this rotation is likely due to a collision, as Haumea is situated within the Kuiper Belt.



Dwarf planet sizes shown relative to Earth's Moon

HISTORY'S DEADLIEST WARRIORS

Lethal fighters who could strike fear into the hearts of even the most battle-hardened enemy

Throughout history, many soldiers from across the world have been contenders for the title of the deadliest warrior, but who really was the most formidable? It takes more than just sheer strength or bloodlust to be considered a legendary fighter.

Most important of all is weaponry; even the toughest soldier can be defeated in a one-on-one dual by a rival with superior firepower. As the old adage goes, don't bring a knife to a gunfight, and the best fighters are always equipped for the job, whether it's a huge pitched battle or a covert operation. A popular theory as to why Custer's men were trounced at Little Bighorn was the fact that the Sioux warriors may have wielded superior rifles to the US Army.

Just as essential as having the right tools is using the right tactics. With a well-planned and efficiently executed strategy, soldiers can outmanoeuvre and outthink a numerically superior force or a physically stronger enemy. In a hypothetical battle between a samurai and ninja of Japan, for example, the use of underhand tactics could easily give the ninja an upper hand against a samurai bound to his moral code and obligated to fight with honour.

Finally, a deadly warrior must have the right attitude and appetite to emerge victorious. Whether it's to protect their homeland or simply earn a wage as a mercenary, a fighter with a purpose is much more dangerous. During the Crusades, Christians and Muslims fought to uphold their religious values and would take to the battlefield again and again in the name of their faith.

Ranging from ancient times to the modern era, read on to learn about some of the deadliest warriors in history. Any soldier would want these legendary fighters standing by their side on the eve of battle.

CIRCA 476-206 BCE

Qin soldier

The military that fought ruthlessly to unify China

The Qin Dynasty was a period of great progress for China. The new emperor Qin Shi Huang made a series of sweeping changes that unified the country and modernised its military. In came China's first professional conscripted army, staffed by formidable soldiers and led by skilled generals. Qin soldiers used some of the most advanced weapons during the era, from sharp iron swords to powerful crossbows.

Their role on the battlefield as shock infantry was supplemented by more heavily armed foot soldiers, as well as flanking cavalry and chariots. The warriors that battled on horseback were held in the saddle by a new invention, the stirrup, giving them greater balance than their adversaries. Some of their enemies were worthy foes, in particular, nomadic tribes from the north with mounted archers. But fuelled by a desire for conquest and loyalty to their emperor, the Qin often held their own in battle.

Notable battle... QIN'S WARS OF UNIFICATION 236-221 BCE

Hairstyle
A Qin soldier's hairstyle denoted rank as well as his unit. Braids in a leather cap were a popular choice that didn't obstruct the fighter in battle.

Ribbons
The number of ribbons fastened to the chest plate was another way of indicating the soldier's rank.

Bronze sword
Qin swords were originally made from bronze, but were later replaced with tough iron.

Armour
Light robes, padded trousers and iron-riveted armour allowed the well-protected warriors to remain nimble.

WEAPONS OF CHOICE
CROSSBOW, BRONZE SWORD

The Terracotta Army is made up of ceramic versions of Qin soldiers. The statues were buried with the emperor in his tomb to accompany him in the afterlife

CIRCA 400 BCE-476 CE

Roman legionary

One of the ancient world's finest armies comprised dedicated, hardened soldiers

The Roman legions were the finest fighting force on Earth for hundreds of years. Manned by well-drilled legionaries, they conquered most of Europe as well as parts of Africa and Asia Minor.

At the height of Roman power, the primary tactic was to throw a spear called a pilum into the enemy masses. It would either impale them or stick in their shields, rendering them unusable. After this, the legionaries drew a short sword, called a gladius, and charged at their foes. Legionaries first wore chain mail but later changed to lorica segmentata. These overlapping metal strips were just as protective but allowed the soldiers to be more agile in combat.

Despite being ferocious warriors in their own right, the prowess of the legionary was complemented by intelligent strategies. Formations like the testudo (tortoise) and siege weapons like the ballista could often be the difference on the battlefield and helped legions overwhelm opposing forces larger than their own. The Roman legions were also often better prepared than their enemy. Legionaries carried saws, rope, pickaxes, cooking pots and rations to set up camps deep into enemy territory.

In the later days of the empire, Roman tactics and armour changed as auxiliary soldiers sourced from around the empire began to fill the ranks. Being a legionary was a well-respected career in the empire, and victorious generals were treated to celebratory processions on their return to Rome.

Notable battle...
BATTLE OF PYDNA, 168 BCE

Helmet
Called a galea, the Roman helmet absorbed blows to the head and protected the side of the face.

Pilum
A type of heavy javelin, the pilum had a strong tip and was weighted in such a way that it could pierce enemy armour.

Gladius
Unsheathed after the pilum had been thrown, the gladius would be used in tight melees to thrust and stab the enemy.

WEAPONS OF CHOICE
PILUM, GLADIUS, PUGIO

Chain mail
Even though Romans are often associated with lorica segmentata armour, legionaries also wore chain mail.

Sandals
The Roman legionary marched in thick, heavy sandals that were stuffed with wool or fur in cold weather.

Scutum
The iconic rectangular wooden shield protected the body and was glued carefully so it could interlink in the testudo formation.

© WIKI: Mary Evans

Roman training

Legionaries were trained to be superior to their enemies. To become part of the legion, the soldiers would be judged on their height, their eyesight and their physical fitness. Recruits were taken on from the age of 18 and would be expected to march up to 30 kilometres a day. A huge emphasis was placed on training, from battlefield formations to swordplay. In specialised training schools, legionaries fought with wooden swords and could lose rations if they did not perform well.

8TH-11TH CENTURY

Viking raider

These brutal warriors devastated coastal towns right across Europe

Anglo-Saxon Britain was assaulted by a series of raids by Norsemen from Scandinavia. Pitching their longboats up on the shore, Vikings pillaged the local area before returning to their ships with valuable plunder. As time wore on, the attacks became more and more frequent and an area known as the Danelaw was established, encompassing northern and eastern England. Wealthy Vikings used double-edged swords, but the majority of fighters carried axes or spears into battle.

The Vikings didn't have standardised tactics, giving them greater variety on the battlefield. Warriors called berserkers went into battle brandishing huge two-handed axes that they used to hew down anyone who got in their way.

The Vikings had a rich appetite for battle as well as an upbringing based on the necessity of war. The longboat helped initiate rapid attacks that would strike an enemy before its forces could retaliate. These tactics helped them conquer not just parts of the British Isles but also territories in Spain, France and Russia. The emperor of the Byzantine city of Constantinople even had his own Norse bodyguards, the Varangian guard, who were some of the toughest mercenaries of the era.

Notable battle...

ATTACK ON LINDISFARNE 793 CE

Ringed mail
Chain mail coats were worn by some cheiftains into battle.

Iron dome
Viking helmets did not have horns but they did have visors that helped protect the wearer's face.

Weapon
The most popular viking weapons were axes, swords and spears.

Keeping warm
In cold temperatures on land and at sea, a thick under-tunic was worn below the armour.

Round shield
Circular shields were made of wood and iron and attached to the side of a longboat when travelling.

WEAPONS OF CHOICE
SWORD, AXE, SPEAR

"The Pope promised that anyone who fought would be forgiven their sins"

Bascinet
The iconic fully enclosed Crusader helmet protected the face and the neck.

From mail to plate
Early Crusader knights wore chain mail, but this later changed to more durable and protective plate armour.

Broadsword
The Crusaders' swords weren't always sharp – some were more effective as clubs rather than cutting instruments.

Kite shield
The kite or tear shaped shield could be strapped on a Crusader's back to carry on long journeys.

WEAPONS OF CHOICE
BROAD-SWORD

11TH-13TH CENTURY

Crusader knight

Clad in protective armour, these western knights fought in holy wars approved by the Pope

Between 1096 and 1272 there were a total of nine crusades to the Holy Land. The foot soldiers of these Christian armies fought to reclaim Muslim-controlled cities like Jerusalem, which they believed to be rightfully theirs. Pope Urban II initiated the First Crusade, promising that anyone who fought would be forgiven for their sins.

The Crusaders' iconic look was completed with a red cross emblazoned on a white surcoat. This was worn to identify each knight as a Christian as well as protecting the metal armour from the hot Sun.

The knights fought both on horseback and on foot as the ownership of the Holy Land changed hands between the Crusaders and the Saracens frequently. Many bloody battles were fought as huge losses mounted on both sides. Both forces still continued fighting undeterred though, fuelled by religious passion and an unwavering belief that they were dying in their god's name.

Notable battles...

SIEGES OF ANTIOCH (1097-1098), SIDON (1110) AND ACRE (1189-1191)

1325-1521

Aztec eagle warrior

The warriors of the Sun who formed an elite fighting force

Prior to the arrival of the Spanish conquistadors, the Aztec Empire dominated vast areas of modern-day Mexico. One of the infantry types that helped maintain control were the eagle warriors. Along with jaguar warriors, they formed an elite unit of Aztec society that was renowned for its military prowess.

To be part of the society, an Aztec had to prove their worth on the battlefield by capturing a set number of enemy soldiers to be used in sacrificial rituals. The aim of returning foes for sacrifice meant that most of the eagle warrior's weapons were designed to wound, not kill.

The Aztec society did not have the technology to smelt metal so they used the world around them to arm themselves. Rocks were collected as ammunition for slings, turkey feathers were used to fletch arrows and tunics were soaked in salt so they would crystallise and harden. Eagle warriors also carried unique weapons like the atlatl, a spear and dart throwing device, and the macuahuitls, a blunt wooden paddle with sharp glass blades protruding from it.

Notable battles...

FALL OF TENOCHTITLÁN 1521, BATTLE OF OTUMBA 1520

Warriors of the Sun
Warriors wore a feathered headdress and wooden headgear that symbolised a bird's open beak.

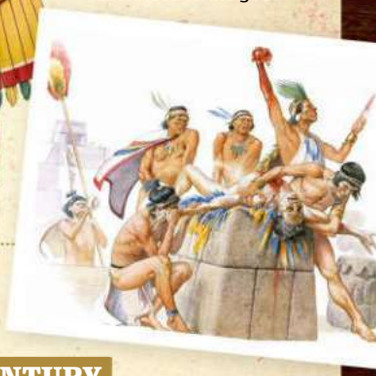
Protection
The warriors wore a quilted cotton tunic and carried a brightly coloured, feathered, round leather shield called a chimalli.

Macuahuitls
A favourite weapon was the macuahuitls, a wooden paddle with glass made from volcanic rock embedded in it.

WEAPONS OF CHOICE
MACUAHUITL, ATLATL

Other weapons
As well as spears, eagle warriors carried slings and bows tipped with either rock, bone or obsidian.

Captive soldiers were often gruesomely sacrificed to the gods



10TH-17TH CENTURY

Ninja

With stealth as a priority, ninjas struck silently from the shadows

Among the most famous assassins in history, the ninja were dangerous adversaries in feudal Japan. Also known as shinobi, in folklore the ninja were first formed to fight back against oppression from the ruling class by a rogue samurai who went against the bushido code.

They practised ninjutsu, the art of stealth, which taught special ninja combat skills and how to remain hidden. Ninjas were the opposite of the samurai, and rather than having codes based on honour like Bushido, they would happily covertly kill their enemies, an act considered immoral by the samurai. But this didn't mean that the two were enemies, instead, the ninja were often employed to aid the samurai.

Contrary to popular depictions, ninjas didn't just wear black; they dressed to blend in, so they would just as likely be clad in civilian clothing to avoid detection. In combat, ninjas would use standard Japanese weapons of the era, but also wielded their own special equipment. The shuko was a small device used for traction when scaling walls and a tessen was an inconspicuous metal fan that could be used as a weapon.

Ninja combat may not have been just reserved for men, either; tales of female ninjas, or kunoichi, described their dressing as servants or dancers to secretly infiltrate forts and compounds to get closer to a target.

Notable battles...

NANBOKUCHO WARS 1331-1392, ONIN WAR 1467-1477

Sneaky operations
Ninjas were especially useful in sieges, infiltrating castles and distracting the surprised defenders.

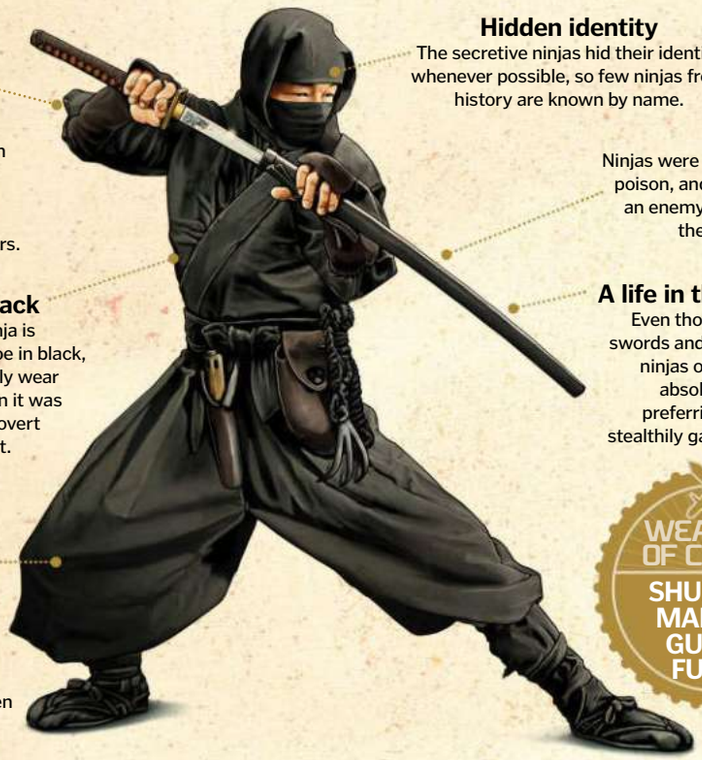
Dressed in black
The archetypal ninja is dressed head to toe in black, but they would only wear this attire for when it was needed, such as covert operations at night.

Martial arts training
Ninjas were trained in martial arts like jujitsu, so they were a dangerous foe even when unarmed.

Hidden identity
The secretive ninjas hid their identity whenever possible, so few ninjas from history are known by name.

Weaponry
Ninjas were experts at using poison, and would add it to an enemy's food or infuse their blades with it.

A life in the shadows
Even though they carried swords and other weapons, ninjas only fought when absolutely necessary, preferring a silent kill or stealthily gathering secrets.



WEAPONS OF CHOICE
SHURIKEN, MANRIKI-GUSARI, FUKIYA

Ninja tool kit

An array of weapons and accessories helped ensure ninjas always had a trick up their sleeves

Kakute
Similar to a knuckleduster, kakute were small, spiked iron rings worn around the fingers. They were an asset in hand-to-hand combat.

Shuriken
These throwing stars could quickly and secretly eliminate targets from distance. They were small enough to be hidden in clothing.

Fukiya
Blowpipes launched poison darts at enemies or sent secret messages to allies. They could also be used as breathing straws.

14TH-19TH CENTURY

Ottoman janissary

The elite infantry of the Ottoman Empire

WEAPONS OF CHOICE: BOW, ARQUEBUS, SWORD

For centuries the Ottoman Empire's mighty army was led by janissaries. The first force was formed around 1380 by Christian prisoners captured after successful Ottoman campaigns in Europe. Aged between six and 14, they were taken from their homeland and bred for battle. After being drafted into the army, they became the property of the sultan and acted as his personal bodyguards.

The janissaries were forced to observe strict rules and were trained to a high standard as disciplined and skilful warriors. As the sultan's most trusted guards, the companies resided in barracks and were constantly drilled for a life of war. The janissary commander was called the agha and ranked above other commanders in the Ottoman military.

Janissaries used swords and rifles as they moved quickly to overwhelm fortresses or to outflank cavalry. On the battlefield, janissaries were recognisable due to their distinctive headgear. They also fought at sea, using their rifles to fire at mariners on enemy ships. They gained a reputation as some of the best marksmen in the world, deploying devastating walls of fire.

In peacetime they also served in Ottoman cities as policemen. At their peak in the early 19th century, there were over 100,000 janissaries and the Ottoman Empire represented one of the finest fighting forces in the world.

Notable battles...

SIEGE OF CONSTANTINOPLE 1453
BATTLE OF MOHÁCS 1526

Headgear
A janissary's headgear was unique and designed to strike fear into enemies, who could recognise the formidable force from a distance.

Robe
A felt robe was worn in place of armour. Lightweight and flexible, it allowed janissaries to move swiftly and engage in naval operations.

Axe
When fighting at close quarters, a janissary would swing their axe, hacking away at anyone that crossed their path.

Breeches
Long robes were stuffed into breeches so they were out of the way both during marching and in the midst of battle.

Primary weapon
Starting off as archers, janissaries soon modernised and wielded arquebuses, becoming some of the most accurate marksmen in the world.

Secondary weapon
With its curved blade the yatagan sword was useful on the battlefield as well as an enduring symbol of the janissary.

War paint
A Sioux warrior's face and body were covered in war paint, and bird feathers were worn in the warrior's hair.

Bow and arrow
The Sioux bow fired iron arrows over a short range and some were backed with animal tendons to provide extra power.

Shield
The small shield was made of animal skin or leather and could deflect enemy arrows.

Tomahawk
Before rifles were introduced by settlers, axes were used as both melee or projectile weapons.

PRE-EUROPEAN COLONISATION-1890

Sioux warrior

Native American warriors who preferred to count coups rather than draw blood

WEAPONS OF CHOICE: BOW, SPEAR, AXE, RIFLE, COUP STICK

Unlike many of the other warriors on this list, the Sioux seldom fought in large numbers. They preferred to attack in small raiding parties that focused on stealing horses or avenging a fallen comrade rather than occupying territory.

The Sioux, like other Native American tribes, did not believe in the ownership of land, but they did compete with rivals like the Crow for hunting and living space in the summer months. Both Sitting Bull and Crazy Horse were Sioux warriors, and it was any young man's ambition to prove their status within a tribe. In Sioux warrior societies it wasn't considered heroic to die, and instead the ultimate show of courage was to touch an enemy with a coup stick.

Enemies that were killed were scalped. This, the Sioux believed, prevented enemies from revisiting warriors in the afterlife, and scalps would be hung as spoils of war outside tips and on spears and shields.

Notable battle... BATTLE OF LITTLE BIGHORN 1876

PRE-EUROPEAN COLONISATION-19TH CENTURY

Zulu warrior

The men who defied the European imperialists

Zulus were divided up into regiments of hundreds or thousands of warriors called an ibutho. Younger unmarried men comprised the main fighting force, and to maximise their time in service, chiefs often didn't let their troops marry until their mid-30's. When a Zulu was married, they could choose to leave the ibutho and from then on were only required to fight in times of war.

Shields were only issued in wartime; Zulus were not allowed to own one in peacetime to help quell potential civil war. Younger regiments tended to have darker shields while more experienced contingents defended themselves with lighter coloured versions. The shields themselves were used to knock enemies off balance before stabbing them with short spears. As well as being traditional, it helped Zulu leaders identify different units on the battlefield. There wasn't a standing army and Zulu warriors returned to their homes between conflicts.

The army didn't have any sort of supply system and lived off the land. This made operations short but often decisive. The Zulus knew the lay of their land better than anyone, which made ambush attacks highly effective. Their prowess in battle enabled the Zulus to conquer rival tribes and made them more than a match for the invading Europeans .

Notable battles...

BATTLE OF ISANDLWANA 1879, BATTLE OF RORKE'S DRIFT 1879

Assegai
Equipped with a sharp, pointed blade, this spear was used to stab enemies from behind a large shield.

Modern firearms
As well as spears, Zulu warriors also wielded rifles that had been imported into Africa by settlers or taken from defeated foes.

Stamina
With no supply train or heavy armour, Zulu forces could cover over 30 kilometres in a day.

Headdress
Zulu regiments wore distinguishing headdresses so their commanders could orchestrate battles from a distance.

Isihlangu
A Zulu war shield was made from cowhide and when beaten with a spear, made a loud intimidating noise.

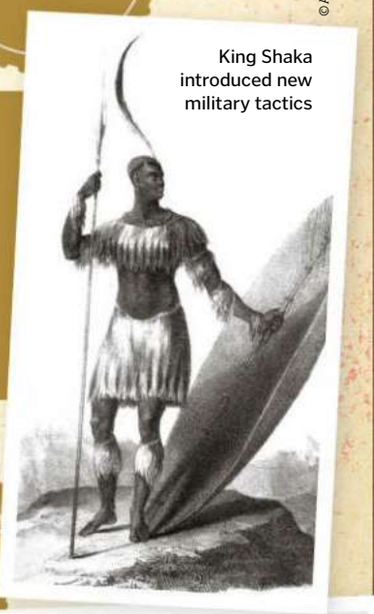
Cowhide
The cowhide used to make the shields was made extra durable by drying it in the Sun, burying it under manure and then hitting it with rocks.

WEAPONS OF CHOICE
ASSEGAI, RIFLE

Horns of the buffalo formation

When the Zulus delivered a crushing defeat to the British at the Battle of Isandlwana in 1879, they had their tactics to thank. The formation was pioneered by Zulu king Shaka and involved a strong central core of warriors flanked by horns – two units of light troops. As the enemy moved to engage the strongest Zulu units in the centre, they would be flanked and encircled. This strategy was devastatingly effective against local tribes but was less successful against the British, especially at Rorke's Drift, where concentrated rifle fire prevented the Zulus from getting in close. However, against the scattered British forces at Isandlwana, it led to an emphatic victory.

The two flanking horns would pressure the enemy toward the main body of the Zulu force.



King Shaka introduced new military tactics

1815-PRESENT

Gurkha

Loyal and fearless, they were a vital asset to Britain in WWI

During World War I, Gurkhas were some of the finest soldiers on the side of the Allied powers. They travelled from their native Nepal to many theatres of the war, including the treacherous cliffs of Gallipoli and the blood-soaked fields of the Western Front. Time and again, the brave Gurkhas led assaults on key positions.

Gurkhas were first enlisted by the British in 1815 and around 3,500 still serve the British Army. Almost 2,000 were awarded gallantry awards during The Great War and several have received the Victoria Cross. Their motto is 'better to die than be a coward'.

Notable battles...

BATTLE OF LOOS 1915, GALLIPOLI CAMPAIGN 1915-1916

Battlefield courage
Gurkha regiments universally wore this headgear during WWI for traditional reasons.

Kukri
A distinctive curved knife made of tempered steel, the kukri was a lethal weapon in practiced hands.

Weapon and tool
The kukri can also be used to chop food and wood. An old legend stated that it had to draw blood every time it was drawn.

WEAPONS OF CHOICE
KUKRI

Over 200,000 Gurkhas served as allies of the British in the two World Wars

Swiss Army knives

The multifunctional pocketknife that has become an incredibly useful tool for soldiers and civilians alike

The origins of the Swiss Army knife lie in the late 19th century. In the small village of Ibach, cutler Karl Elsener decided to create a foldable tool for his country's armed forces. Its purpose was to help troops open canned rations, and disassemble and service their rifles.

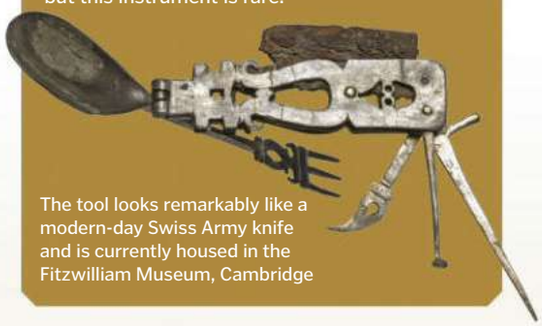
The first model was called the soldier knife, and when it was supplied to the army's rank and file in October 1891 it was immediately popular. The original design contained a blade, a reamer hole punch, a can opener and a screwdriver; all tucked inside the handle until required. In addition to the original knife, an improved 'Schweizer Offiziersmesser', or Swiss Officer's knife, was created. This version included two new tools – a small blade for scraping mistakes off documents and a corkscrew to open wine bottles. The knife was later sold to civilians and became popular with farmers and climbers.

As the popularity of the device grew, so did the number of rivals attempting to make their own versions. In response, Elsener made sure that all of his authentic knives had the same symbol emblazoned upon them – a Swiss flag on a shield. By 1921 the knives were being made with stainless steel, which made it both stronger and also easier to clean. Ten years later, the factory in which the knives were made was automated, which improved quality standards. The design was developed further with the addition of several more useful tools including a wood saw, nail file, toothpick, tweezers and scissors.

The knives became even more popular after World War II when American soldiers brought them home. Replicas are now produced all over the world and it remains an incredibly useful alternative to carrying numerous different knives and tools. Over 15 million are made each year and there are now over 400 variants.

The Roman multi-tool

Several decades ago, archaeologists working in the Mediterranean uncovered a device that bears a striking resemblance to a Swiss Army knife. The instrument was dated to between 200 and 300 CE and is believed to have originated in ancient Rome. The 15-centimetre-long silver tool is believed to have been used primarily as portable cutlery by travellers. Its foldaway equipment comprises a fork, spatula, spoon, knife and a spike that was used to pry snails out of their shell. It may also have been used to take out stones from horse's hooves. As it was crafted from silver, not bronze, it's thought that the utensil was a luxury item, only available to the wealthiest in Roman society. Bronze knife and spoon tools were common, but this instrument is rare.



The tool looks remarkably like a modern-day Swiss Army knife and is currently housed in the Fitzwilliam Museum, Cambridge

Evolution of the Swiss Army knife

Since it was first distributed in 1891, the Swiss Army knife has been refined into a highly versatile modern multi-tool

Original tools
The first Swiss Army knife included just four tools: a short blade, screwdriver, reamer and can opener.

Aluminium alloy
In 1951, Swiss Army knives were made lighter by using an aluminium alloy rather than nickel or silver.

Tradition
Swiss soldiers are still issued with Victorinox pocket knives; this latest iteration was introduced in 2008.

Saw
The metal saw is made using a hardening process that gives it the strength needed to cut through tough materials.

Casing
The original Swiss Army knife had a wooden case. Metal and plastic casings are also used in today's models.

Hi-tech additions
Modern Swiss Army knives can include gadgets such as laser pointers, USB drives and even fingerprint scanners.

Red handle
Civilian Swiss Army knives were coloured red so they could be easily found if dropped in the snow.

New tools
The current soldier knife includes 10 tools: a large blade, reamer, bottle opener, wire stripper, wood saw, can opener, key ring and three screwdrivers.

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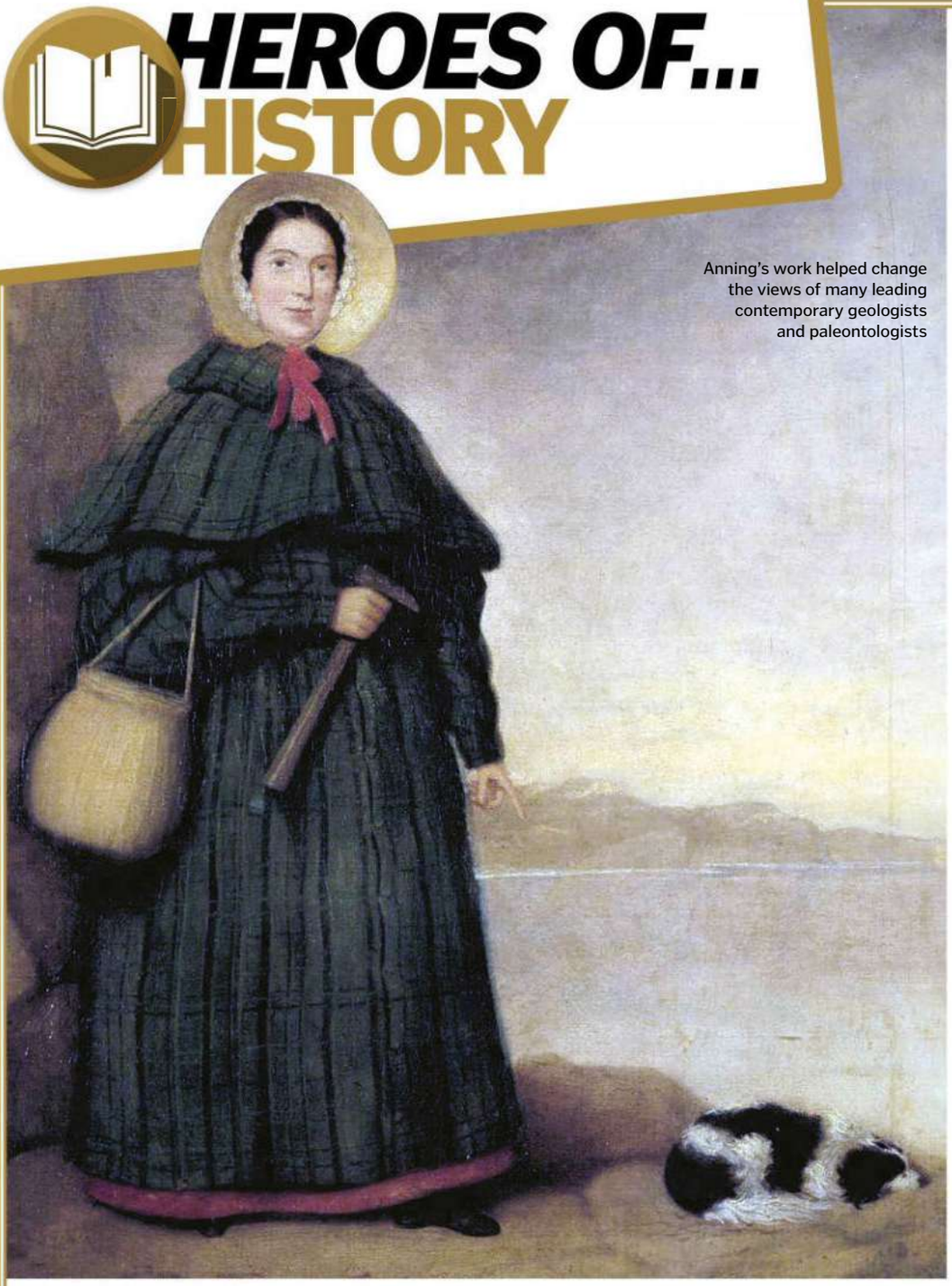


Anning's work helped change the views of many leading contemporary geologists and paleontologists

Mary Anning

A trailblazer for palaeontology who excavated prehistoric fossils and helped broaden scientific study

Born into poverty on 21 May 1799, Mary Anning had to work hard from a young age. She didn't have a formal education and was only taught to read at Sunday school. Raised in the seaside resort of Lyme Regis in Dorset, Mary and her older brother Joseph made a living selling ammonoid fossils to holidaymakers at their father's waterfront stall.

Her life changed in 1811 when Joseph noticed a skull embedded in rock. Curious, the siblings chipped away until an entire skeleton was uncovered. Unbeknown to them, this was the first ever discovery of an ichthyosaurus, a marine reptile from the Triassic period.

There was a huge fanfare over the find, which only escalated when famous surgeon Everard Home wrote a scientific paper on the ichthyosaurus three years later. The fossil was found at an area now known as the Jurassic Coast, a part of Dorset that was underwater when dinosaurs roamed the Earth. The cliffs where Anning grew up were filled with fossils from the Jurassic period, and she would often scour the beach after storms when rocks had been eroded or dislodged by the weather.

Anning noted down every find she made, and after failing to find any new fossils for over a year, in 1821 she made her next discovery, unearthing three more ichthyosaur skeletons. This was followed two years later by an even more impressive find – a complete plesiosaur skeleton. This was so extraordinary that many leading scientists declared it a fake, unwilling to believe that an uneducated 24-year-old could find such remarkable remains. Additionally, society at the time was highly religious and many rejected these discoveries as they conflicted with the teachings of the Bible.

Despite the setback, Anning continued to make more startling revelations. She uncovered belemnoidea fossils, squid-like creatures that were among the first prehistoric animals discovered that had the ability to squirt ink. Anning also dug up fossilised faeces, which helped experts understand the diets of prehistoric creatures. But her biggest finding of all was the first complete skeleton of a pterosaur in 1828.

A LIFE'S WORK

Mary Anning's life of fossil finding on the cliffs of Dorset

1799
Mary Anning is born into poverty on 21 May in Lyme Regis in Dorset, England.

1811
Her brother Joseph finds an ichthyosaur skull and Mary, aged 12, helps dig up the rest of the skeleton.

1814
A scientific paper on the discovery is written and published by the famous surgeon Everard Home.

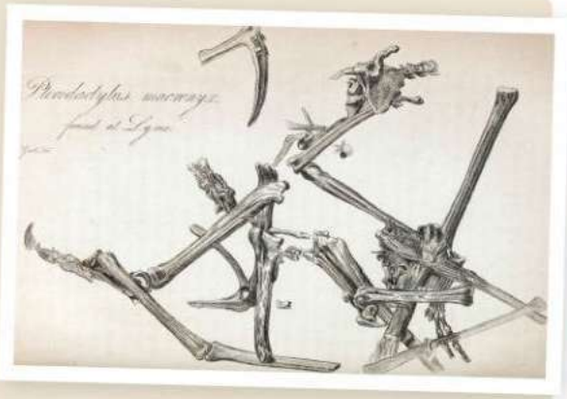
1819
The skeleton is put on display at the British Museum in London, giving the Jurassic Coast national coverage.

1820
After not finding any fossils for over a year, the Anning's are forced to sell furniture to pay rent. Thomas Birch, a local naturalist, helps fund more digging.

Groundbreaker

The first complete pterosaur fossil discovery

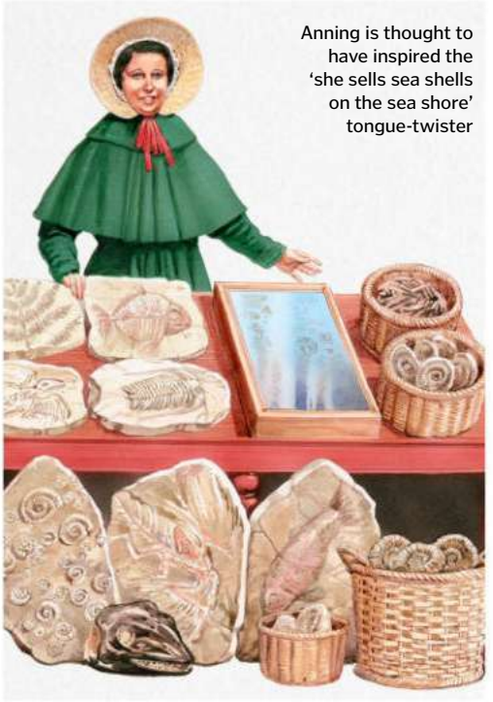
Mary Anning's discovery of the pterosaur *Dimorphodon macronyx* was a turning point. For the first time there was hard proof that many different species of flying reptile had existed in the prehistoric era. It lived 200 million years ago and had shorter wings and a larger head than previous species found in Germany. The fully intact skeleton provided scientists with a physical specimen to study. Additionally, her finding of a squaloraja fossil helped bridge the gap between the evolution of rays and sharks, decades before Darwin's *On The Origin Of Species* was released.



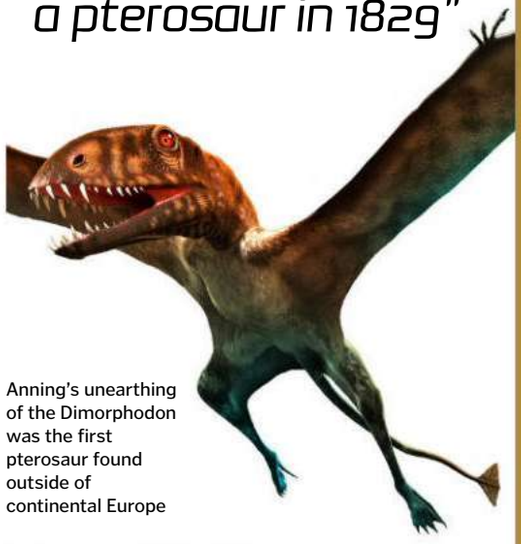
The specimen was the first pterosaur uncovered outside of Germany and the first complete pterosaur fossil found

All of Mary Anning's discoveries helped influence the study of palaeontology as scientists began to take an increased interest in fossilised animals and plants. Her work also prompted people to question the history of the Earth in more detail as well as encouraging girls and those from poorer backgrounds by proving that they could succeed in scientific study, a profession dominated by wealthy upper-class men. She died in her hometown in 1847 from breast cancer, aged just 47. A stained glass window in a local church was made in her memory and is still there today.

"The biggest finding of all was the first complete skeleton of a pterosaur in 1829"



Anning is thought to have inspired the 'she sells sea shells on the sea shore' tongue-twister



Anning's unearthing of the Dimorphodon was the first pterosaur found outside of continental Europe

Anning helped put the Jurassic Coast on the map as a hotbed for prehistoric excavation

Five things to know about... MARY ANNING

1 She was immortalised in song
Mary Anning's life was thought to be the inspiration for a song written in 1908, which included the tongue-twister 'she sells sea shells on the sea shore'.

2 She could speak French
Anning was a keen reader of the works of Georges Cuvier, a prominent French palaeontologist. To help understand his writing, she learned to read French herself.

3 Two fish are named after her
In recognition for her achievements, *Acrodus anningiae* and *Belenstomus anningiae* are named in her honour. The two fish species were found by Louis Agaasiz, who visited the Jurassic Coast in 1834.

4 She was very nearly killed by lightning
A popular story claims Anning nearly died aged just 15 months. Caught in a sudden thunderstorm with her babysitter and two other children, a lightning strike killed the other three but somehow she survived.

5 Her discoveries were painted
Geologist Henry De la Beche was inspired by Anning's discoveries to paint a picture of what prehistoric life may have been like. The painting encouraged many people to speculate about the distant past.

1821
Three more fossilised ichthyosaurs are found, which are up to six metres in length.

1823
Anning finds her biggest discovery yet in December – the complete skeleton of a plesiosaur.

1824
Fossilised animal faeces are dug up, helping experts understand the diets of some prehistoric animals.

1828
Anning finds the first ever pterosaur fossil outside of Germany. This is followed a year later by the first ever complete skeleton.

2010
The Royal Society recognises her as one of ten British women who have made major contributions to the development of science.

The Brown Bess musket

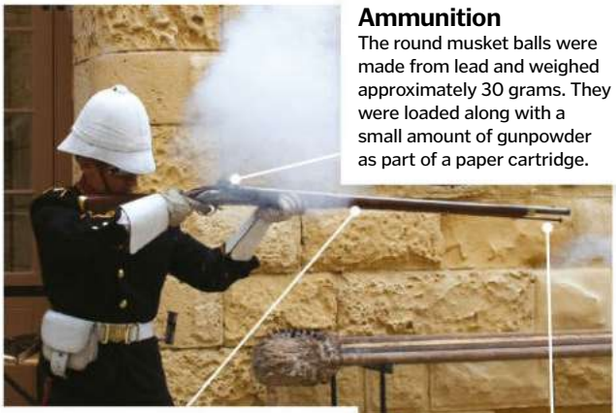
The British Army's weapon of choice against Napoleon's Grande Armée and Washington's revolutionaries

Brown Bess muskets are sometimes credited as 'the weapons that won Waterloo'

The Long Land Pattern Flintlock Musket, or Brown Bess, is the longest serving firearm in the history of the British Army. This popular musket was wielded by British redcoats across the world and used during the American Revolution and the Napoleonic Wars. The Brown Bess was not famed for its firing rate or its accuracy, and was most useful at ranges of 50 metres or less. Rather than sharpshooting, the British tactic was to fire en masse, launching a deadly volley against the enemy. Alternatively, a bayonet could be fixed for a devastating infantry charge.

The famous British Army musket

With its muzzle-loaded flintlock mechanism, the Brown Bess was a reliable all-rounder on the battlefield



Ammunition

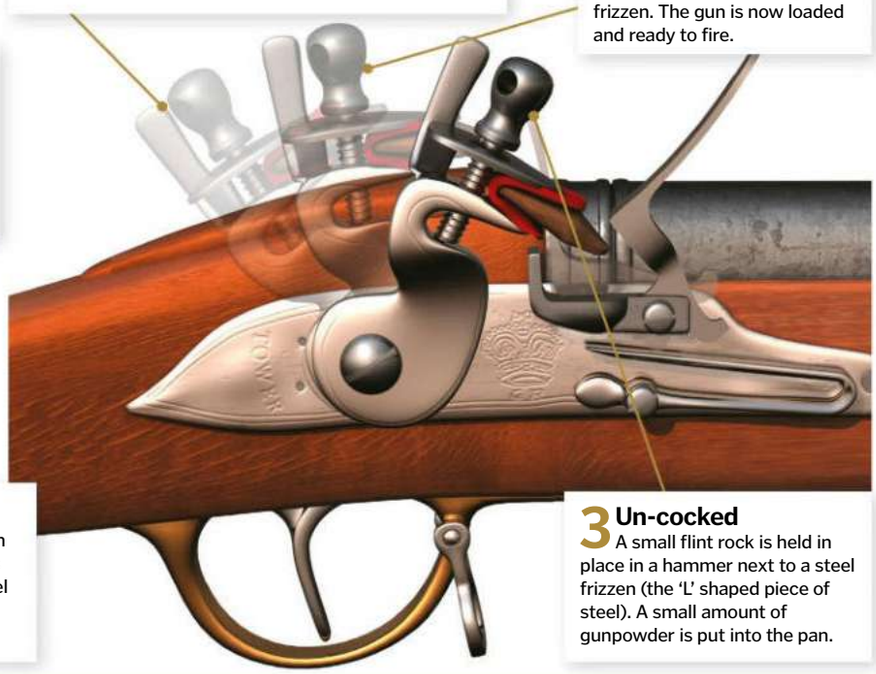
The round musket balls were made from lead and weighed approximately 30 grams. They were loaded along with a small amount of gunpowder as part of a paper cartridge.

Smoothbore barrel

The Brown Bess' barrel didn't have rifled grooves, which affected accuracy. It was particularly inaccurate over long distances and had a maximum effective range of around 100 metres.

Ramrod

The musket was loaded from the muzzle. The ramrod was carried underneath the barrel and was used to push the ammunition into the bore.



1 Full-cocked

As the trigger is pulled, the flint strikes the steel frizzen at high speed. This creates a spark, which ignites the gunpowder, first in the pan and then in the barrel.

2 Half-cocked

The hammer is pulled back into the half-cocked position and the pan is covered by the frizzen. The gun is now loaded and ready to fire.

3 Un-cocked

A small flint rock is held in place in a hammer next to a steel frizzen (the 'L' shaped piece of steel). A small amount of gunpowder is put into the pan.

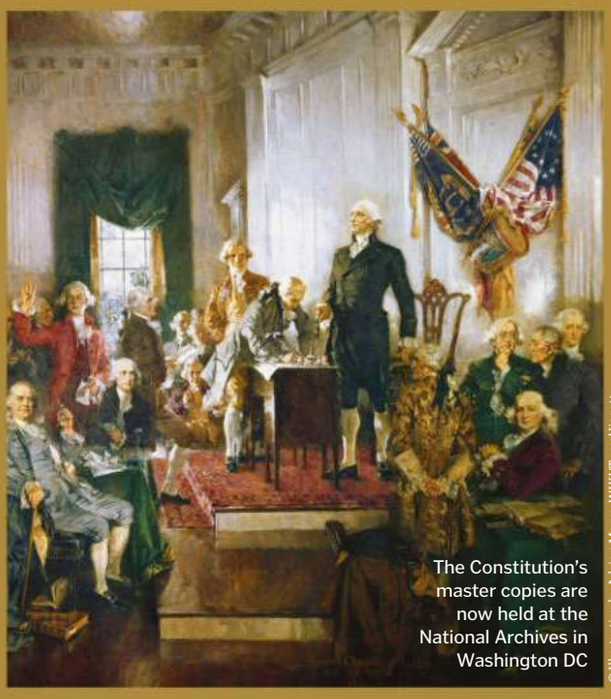
The US Constitution

The iconic piece of parchment that became the supreme law of the land

After victory in the American Revolutionary War, the newly formed United States of America was governed under the Articles of Confederation. Written during the war, it was fast becoming problematic and flawed. 12 of the 13 former colonies (Rhode Island declined to participate) selected representatives to help craft a new article. They were known as the Framers, and after much debate behind closed doors, the US Constitution was born.

The document was signed on 17 September 1787 with 38 signatures, including many who had been Founding Fathers like Benjamin Franklin, James Madison and George Washington. The Constitution was officially approved in July 1789 and had a huge effect on politics as the government was divided into three branches: Executive (President), Legislative (Congress) and Judicial (Supreme Court).

While it was being written, the Framers knew it wouldn't be perfect, so it was designed to be revised. These alterations are the Amendments and there have been 27 so far, with the first ten compiled under the Bill of Rights, which was authorised in 1791. The US Constitution is both the oldest constitution and the shortest governing document in the world, and all US laws stem from it in some way.



The Constitution's master copies are now held at the National Archives in Washington DC

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BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer.*

Sarah Bankes

Sarah is the editor of *Photoshop Creative*, has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Joanna Stass

Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts. She is particularly interested in natural world wonders, innovations in technology and adorable animals.

The ruins of Reactor 4 at Chernobyl were covered by the New Safe Confinement structure in late 2016

Is Chernobyl still radioactive?

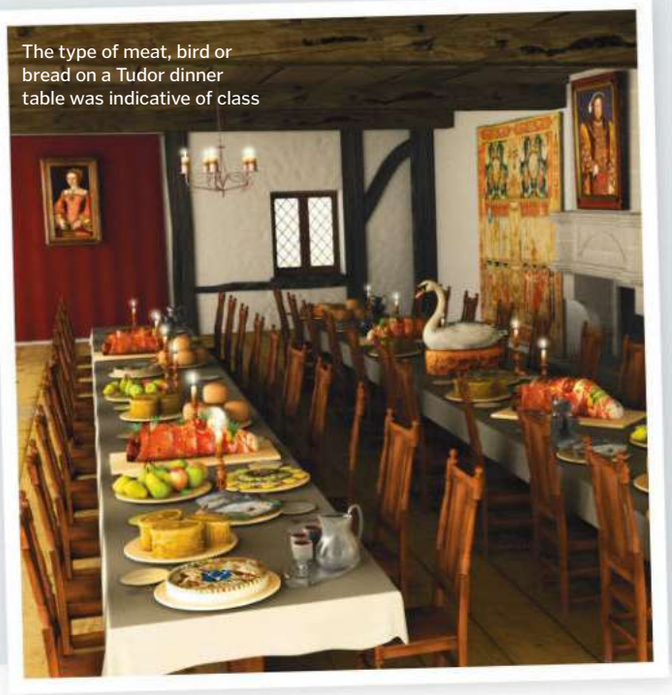
Marcus Lewis

In 1986 a reactor explosion at the Chernobyl nuclear power station released huge quantities of radioactive materials. Radioactivity decays over time, but much of the area around Chernobyl is still dangerously radioactive. It's surrounded by a 2,600-square-kilometre exclusion zone, which isn't expected to be totally safe for human habitation for hundreds of years, although workers and tourists are allowed limited access. The actual reactor ruins, which lay sealed inside a giant concrete sarcophagus to stop radiation escaping, will be radioactive for thousands of years. As the sarcophagus is ageing, a new shield has recently been placed over the top. **TL**

What did the Tudors eat?

Kevin Watson

Tudor England was generally self-sufficient, not needing to rely on imports. People ate a lot of fresh food because storing food was difficult. Even peasants had small pieces of land, so the wealthy and poor kept animals, from chickens, pigs and cows, to ox, venison and wild boar. However, fish was always eaten on Fridays. Fruit and vegetables were plentiful, such as beans, carrots, peas, onions, apples, plums, pears, strawberries and cherries. Everyone ate bread and cheese, but the type of bread and cheese determined the class of a person. Expensive bread was made of white wheat flour, whereas cheap bread was a mixture of rye and wheat. **SB**



The type of meat, bird or bread on a Tudor dinner table was indicative of class

What are the 'poles of cold'?

Oymyakon in Siberia is the coldest inhabited place on Earth

Naomi Isles

We're all familiar with the poles of our planet - the northern and southernmost points according to the spin of the Earth and the position of its magnetic field. But, the Poles of Cold are a little different. These are the places with the coldest air temperatures ever recorded. In the northern hemisphere, the Pole of Cold is found in the valley of Oymyakon in Siberia, Russia. The temperature there can fall to below -50 degrees Celsius on average in the winter, but in spite of the chill, it is inhabited all year round. It can be reached using the Kolyma Highway, or Road of Bones, named for the vast number of prisoners who died building it in the 1930s. **LM**

NASA grew this sunflower on the International Space Station

How are plants able to grow towards the Sun?

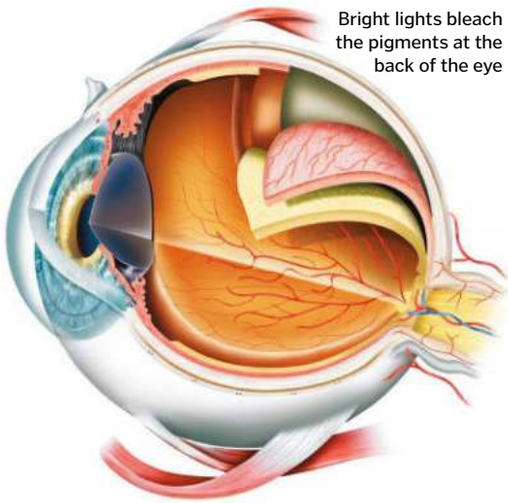
Geoffrey Chang

Exposure to sunlight is critical for plants because their entire source of sustenance comes from photosynthesis. Being able to find 'up' and grow towards it is crucial for their survival. Plants use light-sensitive molecules to detect the direction of the Sun, and produce a hormone called auxin to change the growth of their stems. The auxin is passed from cell to cell until it reaches the side of the stem furthest from the light source. Here, it stimulates growth, causing the stem to bend over and lean towards the Sun. They also use gravity to orientate themselves, and even without light, they will still grow upwards. **LM**

Why can we still see bright objects after shutting our eyes?

Peter Reeves

This is known as an afterimage, and is caused by the effects of the light on the cells in the back of your eye. Your eye detects light using specialised cells packed with sensitive pigments. You have rods, which detect light and dark, and cones, which transmit information about colour. If you look at a bright light for too long, the pigments become bleached, and the nerve cells become fatigued. It takes them a little while to recover, and while this is happening, the area of your eye that was exposed to the light cannot transmit any more signals. The effect is a negative imprint of the image in your vision. **LM**



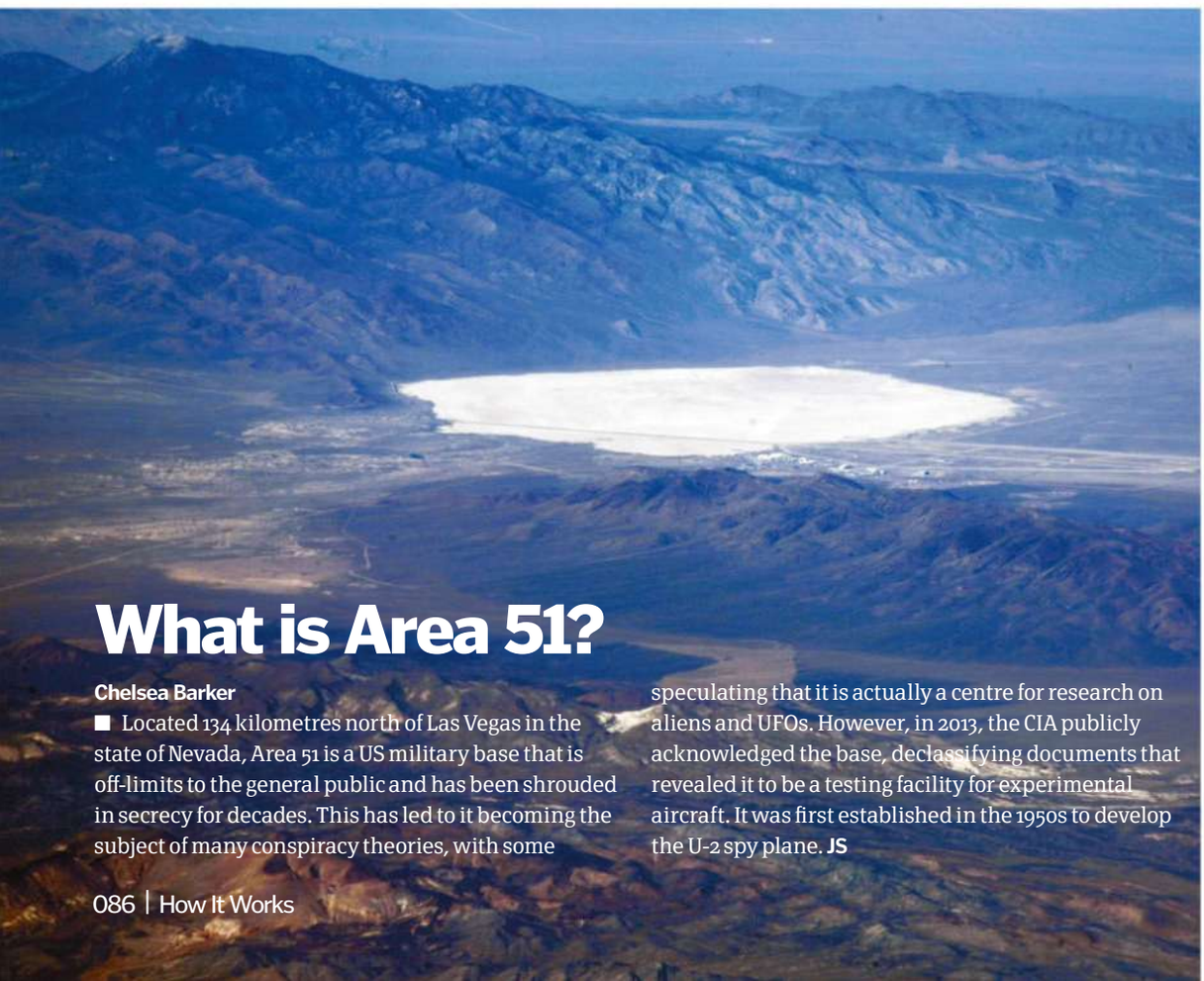
Bright lights bleach the pigments at the back of the eye

BRAIN DUMP

Why do we smile and why does smiling make us feel so happy?

Cosmo MacLellan

Smiling is one of the most basic of human expressions, and is thought to be related to the 'silent bared teeth display' in other primates. Opening the mouth to show off closed teeth is a nonthreatening signal of cooperation, and for us, it has become a reflex way to express happiness. There's a difference between spontaneous smiles and forced smiles. Natural smiles are more symmetrical, and involve wrinkling at the outer edges of the eyes. It's difficult to 'fake' a smile convincingly, and people are normally able to distinguish between the two. However, even though people might be able to tell your smile isn't natural, it is not wasted. Smiling at the right time is a social signal of cooperation, and can trigger a positive response in the people around you. It also affects your mood. Smiling is thought to have a feedback effect on the brain, making you feel happy. **LM**



What is Area 51?

Chelsea Barker

Located 134 kilometres north of Las Vegas in the state of Nevada, Area 51 is a US military base that is off-limits to the general public and has been shrouded in secrecy for decades. This has led to it becoming the subject of many conspiracy theories, with some speculating that it is actually a centre for research on aliens and UFOs. However, in 2013, the CIA publicly acknowledged the base, declassifying documents that revealed it to be a testing facility for experimental aircraft. It was first established in the 1950s to develop the U-2 spy plane. **JS**

FASCINATING FACTS

What is the fastest car in the world?

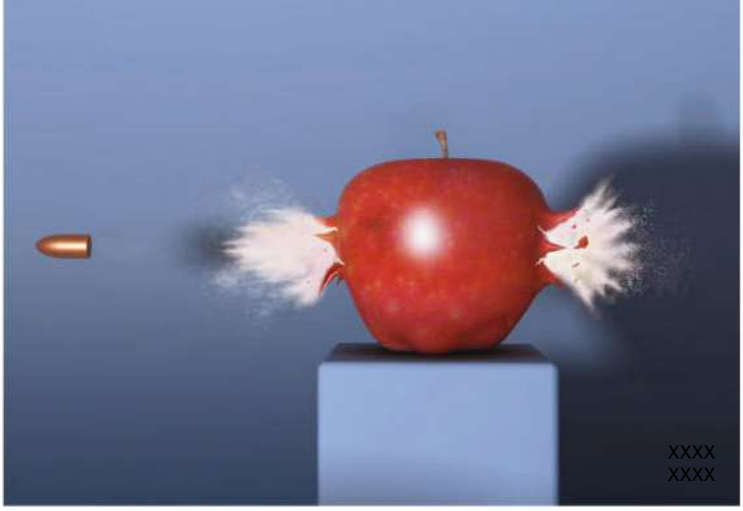
The world's fastest car is the jet-propelled Thrust SSC, which reached a speed of 1,227.985 kilometres per hour in 1997, breaking the sound barrier and the land speed record. **JS**

Who invented email?

Today's email systems are built on many people's inventions, but the first programme for sending electronic mail between computers was created in 1971 by Ray Tomlinson, who also put the @ sign into email addresses. **TL**

How do you define a dinosaur?

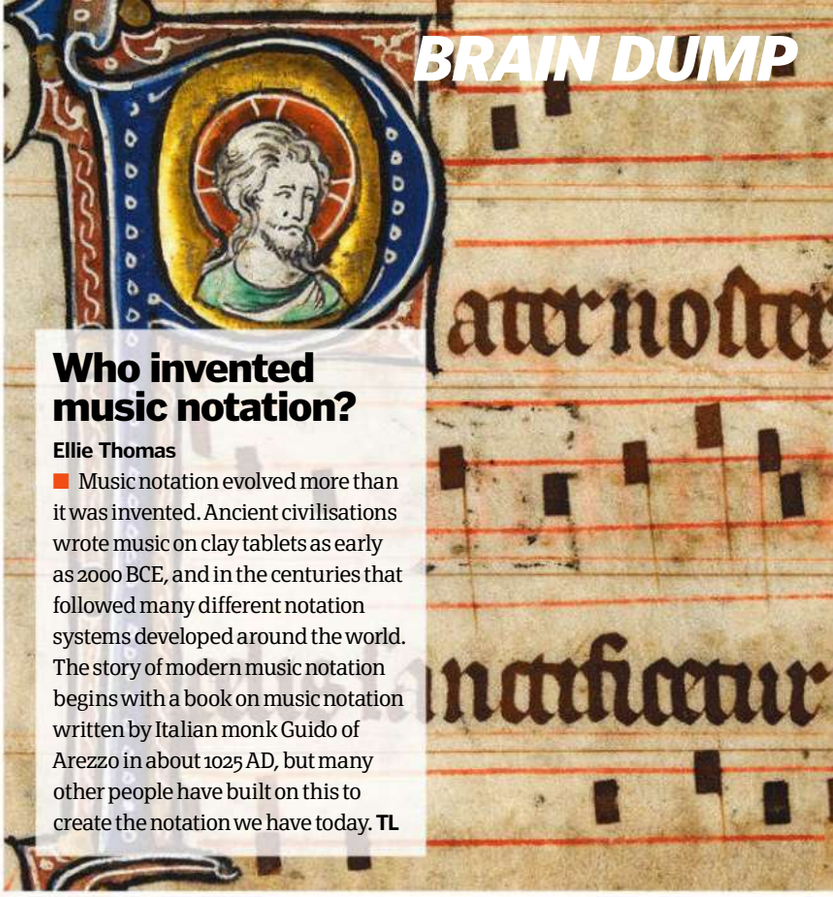
Dinosaurs are formally defined as all the descendents of the last common ancestor of birds and triceratops. By this definition, modern birds are dinosaurs, but flying prehistoric reptiles like pterosaurs are not. **SB**



How do superfast cameras work?

Phoebe Sims

A superfast camera is an electronic device that uses a charge-coupled device (CCD) or a complementary metal-oxide semiconductor (CMOS) active pixel sensor. The sensor is so sensitive to light that it doesn't need to be exposed to it for as long as it would need to be in a typical camera, and is therefore able to record a huge amount of light at a superfast speed. This means that the camera is capable of recording more than 1,000 frames per second into dynamic random-access memory (DRAM). It can then play the images back slowly. **SB**



Who invented music notation?

Ellie Thomas

Music notation evolved more than it was invented. Ancient civilisations wrote music on clay tablets as early as 2000 BCE, and in the centuries that followed many different notation systems developed around the world. The story of modern music notation begins with a book on music notation written by Italian monk Guido of Arezzo in about 1025 AD, but many other people have built on this to create the notation we have today. **TL**

When was the first ever Chinese dynasty founded?

Derek McKintock

The first Chinese dynasty was likely the Xia Dynasty, but there is some disagreement in terms of exactly when it ruled. The traditional chronology, which is based on calculations by Xin Dynasty Chinese historian Liu Xin, states that the Xia ruled between 2205 and 1766 BCE. However, the chronicle of ancient China, *Bamboo Annals,* claims that it ruled between 1989 and 1558 BCE. The Xia-Shang-Zhou Chronology Project therefore concluded that the Xia existed between 2070 and 1600 BCE. The Xia Dynasty included the rule of 17 emperors, but Yu the Great was its first ruler and founder. **SB**

Robots that are near-perfect human replicas make us uneasy

What does 'uncanny valley' mean?

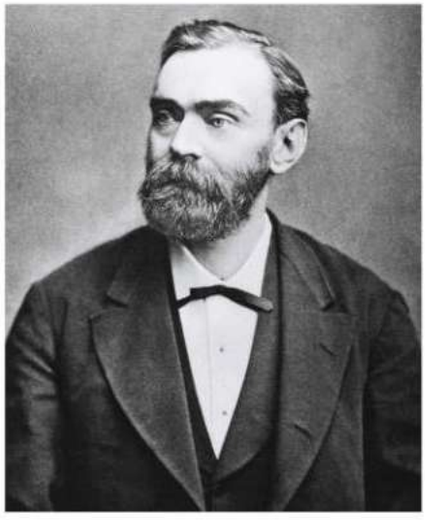
Jim Keith

The uncanny valley is a theory that explains why people become uneasy about replicas of humans. For example, as robots become more human-like we become more comfortable around them, but there is a point at which near-perfect replicas of humans make us uncomfortable. Yet as they become even more like us, our feelings towards them improve again. The dip in emotional response is the uncanny valley. We're not sure why it happens, but it could be because almost-human replicas subconsciously remind us of sickly people, which we have evolved to avoid. **TL**

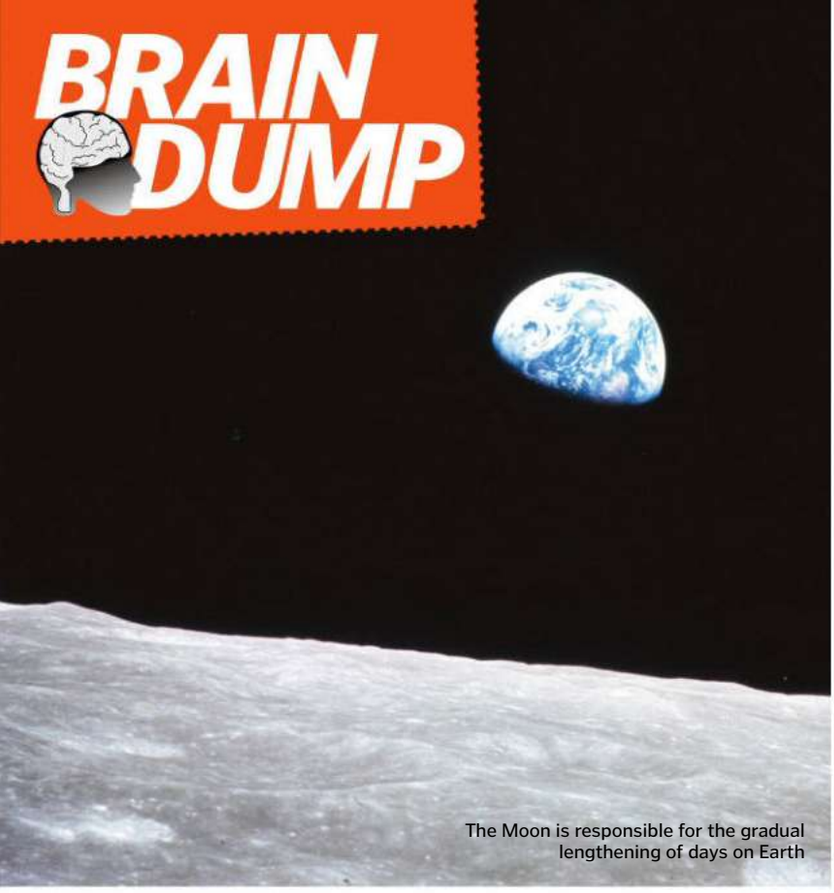
Who won the first Nobel Prize and why?

Reggie Doyle

When he died, the Swedish inventor Alfred Nobel left instructions that his vast wealth should provide annual prizes in physics, chemistry, medicine, literature, and peace, for individuals who "during the preceding year, shall have conferred the greatest benefit to mankind". So there were five first Nobel prizes, awarded in 1901 to: Wilhelm Röntgen, for discovering X-rays; Jacobus Henricus van 't Hoff, for discovering the laws of chemical dynamics and osmotic pressure; Emil Adolf von Behring, for developing a serum for diphtheria; Sully Prudhomme, for poetic composition; and, jointly, to peace activist Frédéric Passy and the founder of the Red Cross, Jean Henry Dunant. **TL**



BRAIN DUMP



The Moon is responsible for the gradual lengthening of days on Earth

Why is the Earth's rotation slowing down?

Freddy Sinclair

The ocean tides caused by the Moon are gradually slowing down our planet's rotation. The Moon's gravity creates a slight bulge on the ocean surface on the side of the Earth that is closest. This bulge in turn exerts a gravitational pull on the Moon. But as the Earth rotates faster than the Moon orbits it, the bulge moves forward in relation to the Moon. As a result, the Earth's rotation slows slightly, giving a little bit of energy to the Moon. Every century, the length of a day on our planet grows by about two milliseconds. **AC**

Why do squirrels twitch their tails?

Anita Frink

Squirrels have many uses for their tails. They act as a counterbalance to help them walk along narrow branches, as an umbrella to shield them from the rain, and as a fluffy blanket to keep them warm while they sleep. However, they also have an important part to play in communicating with other squirrels. Although squirrels can make a range of calls, their tails are their main method for sending signals. For example, if they sense danger nearby they will twitch their tail to warn others, or if they're feeling aggressive they will fluff it up. **JS**

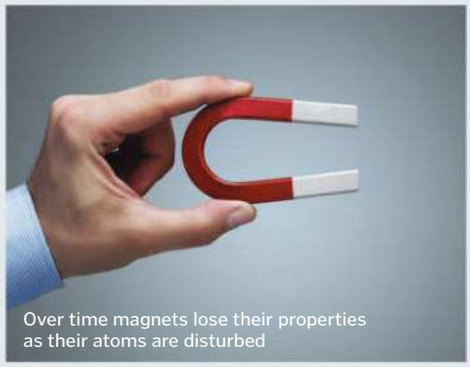
Squirrels shiver their tails when approaching a member of the opposite sex

Why do pigeons bow to each other?

Carly Ledham

The bowing motion between pigeons is part of their courtship ritual, which can take place at any time throughout the year. The male bird will puff up his neck feathers to make himself look bigger and more impressive. He will then quickly walk towards the hen, bowing and turning as he gets closer to her. He continues to bow and pirouette before mounting her. **SB**

Do magnets ever lose their strength?



Over time magnets lose their properties as their atoms are disturbed

Carrie Kendal

Magnets get their magnetic properties from the alignment of their atoms, and can lose their magnetism if something causes these atoms to become misaligned. One way this can occur is if a magnet is heated – the resulting jostling of atoms can disturb their arrangement. Dropping certain magnetic steels can also knock their atoms out of alignment and lose their magnetism. Finally, applying a strong enough opposing magnetic field can also demagnetise a magnet. **AC**

FASCINATING FACTS

How far out does the Sun's atmosphere extend?

The lower layers of the Sun's atmosphere are roughly 2,400 kilometres thick. The outermost layer, the corona, has no real 'edge' since it has a very low density, stretching to several million kilometres. **AC**

How do caterpillar tracks work?

Hayley Todd

Caterpillar tracks are commonly found on military tanks and other heavy machinery, helping them to spread their weight over a larger area to improve traction. They consist of a set of two or more wheels encased inside metal track plates that act like a continuous conveyor belt. At the front and back of the vehicle, sprockets (a type of wheel with teeth that lock onto the track plates) are rotated by the engine. In turn they rotate the track, setting the vehicle in motion. **JS**

Why do some phone batteries suddenly explode?

Rachel McIntyre

Phone batteries have been known to explode when the battery's terminals come into contact, creating a short circuit. A battery contains a positively charged and a negatively charged terminal, separated by an electrolyte. In lithium-ion batteries – the most efficient type – this electrolyte is flammable. Chemical reactions at each terminal create a flow of charged ions through the phone's circuitry. But if the terminals come too close together as a result of damage or a defect, a current can flow directly between the two terminals. This can cause the flammable electrolyte to overheat, triggering a runaway reaction that can cause the phone to catch fire or explode. **AC**

How do you decaffeinate coffee?

Lucas Rathborn

The most widespread decaffeination method strips caffeine from coffee beans using a solvent such as ethyl acetate (which can be derived from fruit and vegetables) or methylene chloride. First the beans are soaked in hot water to make the caffeine soluble, then the solvent is circulated through the beans to draw the caffeine out. The beans are then rinsed and steamed to remove any traces of the solvent. Repeating these steps removes up to 97 per cent of caffeine. Water processing uses a solution of green coffee bean extract, which is rich in flavour compounds, as a solvent. Caffeine is drawn into the solution and then filtered out by a bed of activated charcoal that has been treated to prevent flavour compounds from being absorbed. This process is repeated until over 98 per cent of the caffeine is removed. A final method uses compressed carbon dioxide to remove caffeine from beans. **LM**

No decaffeination method removes 100 per cent of the caffeine from coffee beans

What is a dogleg gearbox?

Timothy Newton

On a traditional manual gearbox, the gears are arranged so that first and second, third and fourth, and fifth and reverse are located across from each other. This makes it easy for the driver to switch between the most commonly used first and second gears. A dogleg gearbox is arranged slightly differently however, with reverse and first, second and third, and fourth and fifth positioned across from each other. This type of gearbox is typically used in race cars, as racing drivers rarely use first gear and so benefit more from being able to switch between second and third gear easily. The name dogleg comes from the more complicated method of switching between first and second on this type of gearbox, as the up-over-up movement required resembles the shape of a dog's hind leg. In non-performance cars, the dogleg gearbox has been phased out in favour of six-speed gearboxes. **JS**

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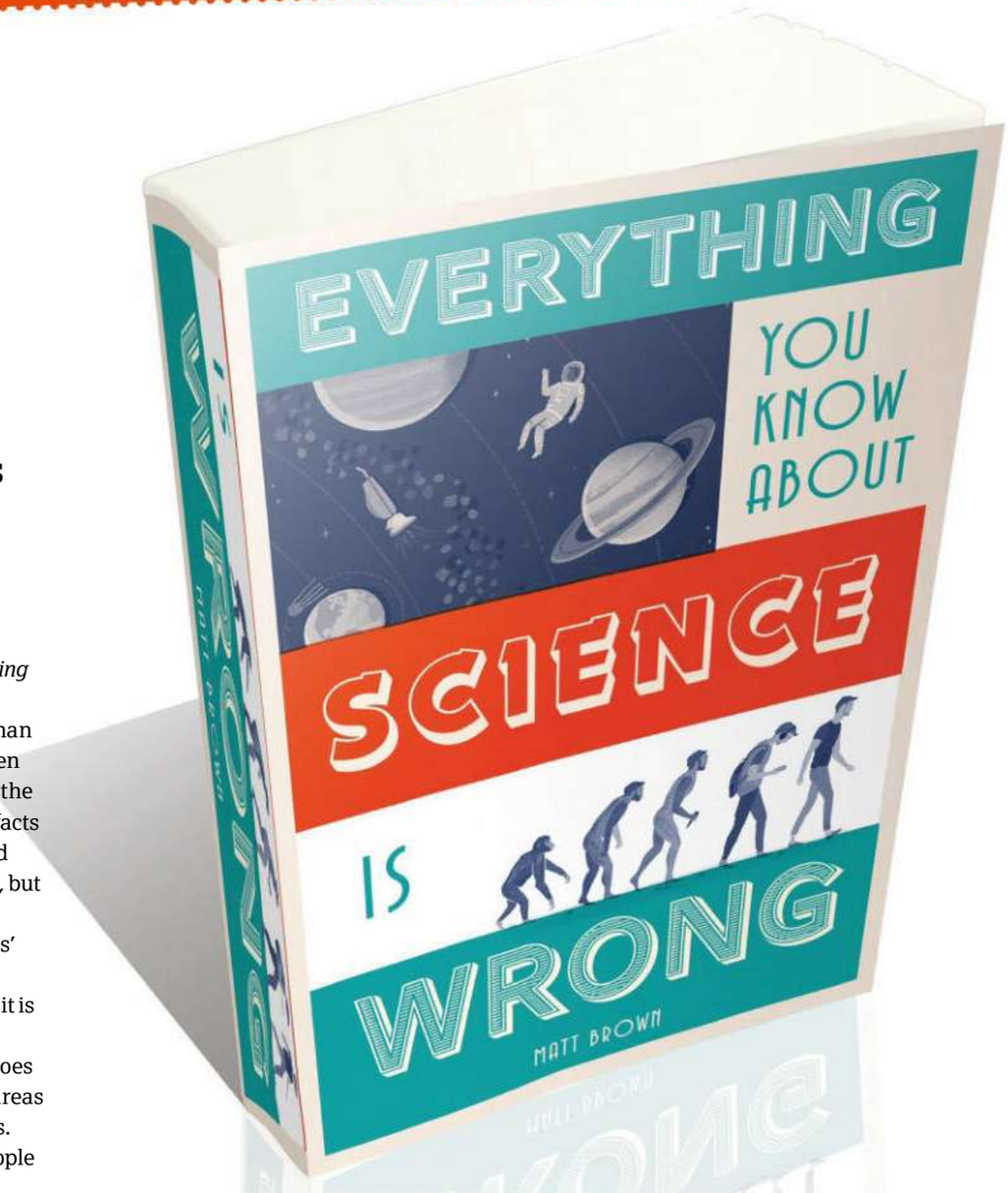
BOOK REVIEWS

The latest releases for curious minds

Everything You Know About Science Is Wrong

Digging into scientific facts to set the record straight

- Author: **Matt Brown**
- Publisher: **Batsford**
- Price: **£9.99 (approx. $12.50)**
- Release date: **Out now**



Matt Brown's introduction to *Everything You Know About Science Is Wrong* is probably much more topical now than he could have ever predicted it would be when he wrote it. He opens his book by describing the difference between real, provable scientific facts and 'pseudoscience' – that is, facts that sound like they are probably scientifically accurate, but are actually misconceptions.

In an era where terms like 'alternative facts' and 'fake news' are so commonly used, and where scientists are being told to stay silent, it is essential to check facts before taking any scientific statement at face value. As Brown goes onto explain, that's excellent practice in all areas of science, and is exactly what this book does.

Brown takes some common 'facts' that people think they know, such as 'water is a good conductor of electricity' and 'astronauts float in zero gravity', and explains why they aren't strictly true. For example, Brown explains that astronauts appear to be floating, but that doesn't mean they are in zero gravity. In fact, they are still feeling around 89 per cent of the gravity we feel on Earth, but because they're hurtling around the planet at such fast speeds, they are really just 'falling' around the curve of the planet at the same speed as the space station around them. Interesting, right?

With any book of this kind – where things you thought you knew are proven to be wrong – there's a risk of the author making the reader feel stupid. Thankfully, Brown does a fantastic job of avoiding this by keeping his tone friendly and lighthearted. Humorous asides will raise smiles now and then, but mostly he simply does an excellent job of explaining complex science in an understandable and non-patronising way, which all readers will appreciate.

Admittedly, some of the 'facts' that he includes are weaker than others. For example, many readers will already know that the Great Wall of China isn't actually visible from space, and that humans aren't the pinnacle of evolution. Thankfully, these are just small pauses in an otherwise entertaining and interesting read.

★★★★★

YOU MAY ALSO LIKE...

Science: The Definitive Visual Guide

Editor: **Adam Hart-Davis**
Publisher: **DK**
Price: **£30 / $50**
Release date: **Out now**

If you want to investigate some of the theories in Brown's work, this is a good place to start. It covers everything from Greek geometry to quantum physics.

101 Bets You Will Always Win

Author: **Richard Wiseman**
Publisher: **Boxtree**
Price: **£9.99 / $14.99**
Release date: **Out now**

Wiseman takes everyday objects and sets them up as bets with your friends that you will always win. This illuminating book then explains the fascinating science that explains how you do it!

Everything You Know About London Is Wrong

Author: **Matt Brown**
Publisher: **Batsford**
Price: **£9.99 / $14.95**
Release date: **Out now**

This book seeks to bust the common myths about the Big Smoke. If you enjoyed Brown's writing in his science book, you'll probably love this too.

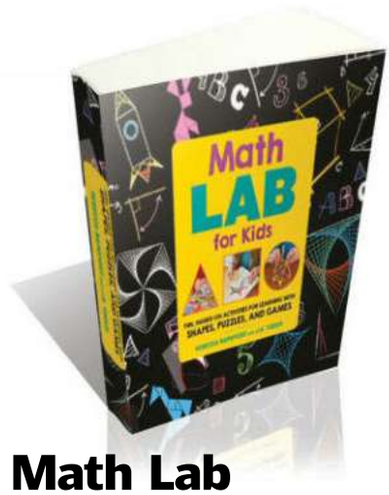
Megatech: Technology In 2050

Predicting the tech revolution

- Author: **Daniel Franklin**
- Publisher: **Economist Books**
- Price: **£15 / $18.99**
- Release date: **Out now**

What will technology be like in 2050? *Megatech* has amassed the opinions of industry leaders, star academics and acclaimed science fiction writers to try and find out. A wide range of technologies are covered, from lab grown, cruelty-free meat to guided bullets and knitted cars. The fact that all the authors are from different backgrounds helps keep the book fresh.

Overall, it's a fascinating book that speculates what the future could have in store. The fact that every idea, no matter how awe-inspiring, is grounded in realism, makes this release a resounding success.



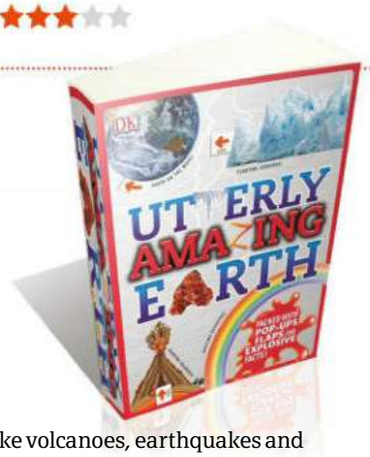
Math Lab For Kids

Maths, but not as you might know it

- Author: **Rebecca Rapoport & JA Yoder**
- Publisher: **Quarto**
- Price: **£16.99 / $24.99**
- Release date: **Out now**

Maths isn't just endless times tables and long division. There's tons of interesting stuff that isn't just to do with numbers. *Math Lab For Kids* introduces children to what it calls a "secret world of mathematics", and encourages the reader to think like a mathematician.

With more than 50 activities inside, there's so much to do, whether it's making prisms and pyramids or building your own toothpick puzzles. The book is intended to be dipped in and out of and not read cover to cover, and will appeal more to younger readers interested in the more practical side to maths.



Utterly Amazing Earth

An entertaining look at the world we live in

- Author: **Dougal Jerram**
- Publisher: **DK**
- Price: **£14.99 / $19.99**
- Release date: **Out now**

Filled with pop-ups, flaps and pull-tabs, *Utterly Amazing Earth* is the perfect book for young minds interested in planet Earth. The interactive illustrations are complemented by mind-blowing facts and figures about the natural world.

The book covers the Earth from surface to core and has pages dedicated to the rock and water cycles and parts of nature like volcanoes, earthquakes and tsunamis. Be sure to look out for the amazing extreme weather pop out too. At 31 pages it's relatively short, and while it may not take long to finish, there are plenty of reasons to revisit the book to check up some facts. Recommended for inquisitive young minds.

30-Second Medicine

Half-minute medical marvels

- Author: **Gabrielle M Finn**
- Publisher: **Ivy Press**
- Price: **£14.99 (approx. $18.50)**
- Release date: **Out now**

Covering 50 topics, *30-Second Medicine* is an insight into the world of illness and treatments. A series of short, punchy entries, it provides an overview of everything from 3D bioprinting to in vitro fertilization (IVF). Biographies of medical pioneers such as Hippocrates are included and vivid descriptions prevent the entries from being boring. Fast facts also add variation. For example, did you know Otto von Bismarck set up the first welfare state? The book isn't (and doesn't claim to be) exhaustive, but it's a welcome addition to the series.

Engineer Academy

A brilliant activity book for budding inventors

- Author: **Steve Martin**
- Publisher: **Ivy Press**
- Price: **£9.99 (approx. $12.50)**
- Release date: **Out now**

This easy to follow yet interesting book is ideal for any younger readers wanting to know more about how the world works. With its stickers, poster and press-out model, *Engineer Academy* is a fantastic starting point for inventive kids. The book is divided into sections that cover subjects from aerospace, alternative energy generation and robotics. Richly illustrated and creatively put together, readers are encouraged to complete several try at home tasks, like making a pulley and designing a water wheel. Rewarding and fun, this is an excellent book for children wanting to learn about engineering.

Destination: Space

The science of the stars in a superbly illustrated book

- Author: **Dr Christoph Englert & Tom Clohosy Cole**
- Publisher: **Wide Eyed Editions**
- Price: **£12.99 / $19.99**
- Release date: **Out now**

Destination: Space is a fantastic read. Starting at the beginning of the universe before progressing on to black holes and space exploration, this is a journey through space for both adults and children. Images are the focus of the book and every turn of the page is welcomed by a beautiful illustration of the Solar System. This is by no means a picture book though, as *Destination: Space* tackles potentially mind-boggling subjects with bite-sized and easy to digest answers. One of the easiest to read yet informative books on space out there, this is a must for anyone interested in the final frontier.

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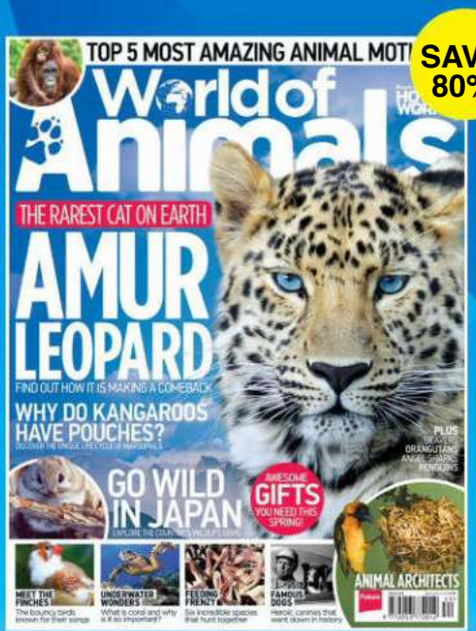

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Make your own fossils

Create fossils in 24 hours, then see if your friends can uncover them like a real archaeologist!

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

1 Plaster of Paris

First, you'll need to mix up some plaster of Paris with water to make a thick liquid. This will form your fossil, but you need to make it slightly thicker than the packet will likely recommend. Combine one cup of plaster of Paris and one cup of water, then mix them together to create a smooth mixture. When left to set the plaster will harden, but first you need a fossil shape.

2 Shell shaped

To create your fossil shape you'll need a shell from the beach, or another interesting item with a good texture. Try to choose something that will look like it could've been encased in rock thousands of years ago. To make your mold, find a shallow bowl and fill it to around two centimetres deep with modelling clay. Press it down with your fingers to make sure it's flat and there are no gaps.

3 Press it in

Push the shell or other item into the clay firmly and leave it there for a few seconds, then carefully take it out. Millions of years ago, dinosaurs would stand in soft clay like this, leaving a footprint. When the water level rose, soft mud would fill this print, and create a fossil when more and more mud layered on top of it over thousands of years.

> "To create your fossil shape you'll need a shell from the beach"

4 Pour and set

To simulate the soft mud, you need to pour the plaster of Paris into the mold that you created in the clay. You'll need to leave it for at least 12 hours so it can set and go really hard. Remember, if this were a real fossil, the process would take thousands of years as the pressure of mud and soil pressed down on the footprint and made the mud into hard rock.

5 Paint it!

When your plaster is set, carefully ease it away from the clay. You might need to ask an adult to do this with a knife if your finger doesn't get it out. Now you can paint your fossil dark brown, and paint the space around it in a lighter brown, to make it look like the real thing. Try burying your finished fossil in sand and challenging your friends to find it, just like real fossil hunters!

In summary...

If you find a shell-like fossil in rocks at the beach, it's possible that you've found a trilobite. These sea creatures had hard shells covering their outer layer, but their insides were soft. When they died, these soft inner parts decayed and minerals filled the space inside them, eventually hardening into fossils.

How to make amazing Sun prints

Create amazing prints with special light-sensitive paper

NEXT ISSUE
BUILD A LOAD-BEARING BRIDGE
MAKE ICY ORBS

1 Prepare the paper
For this project, you'll need some light-sensitive paper that you can buy from most craft shops or online. The chemicals on the paper react to light, but you'll need to work fast to make sure your prints look good. For best results, you should go outside on a sunny day before you start, but once you take the paper out of the packet and pin it to a piece of corrugated cardboard, you'll have to work fast!

"Once you take the paper out you'll need to work fast"

2 Be quick!
As soon as you have pinned the paper to the cardboard, place some feathers or leaves on the paper, arranging them how you want them to look. Try not to move anything while the paper is absorbing the light, as it will make your print look less effective. Leave the feathers or leaves on the paper for a couple of minutes – or longer if you're doing it on a cloudy day – and then remove the feathers and unpin the paper from the cardboard.

3 Wash and dry
As quickly as you can, place the paper into a tray of water. You'll immediately see that the deep blue colour that was left under the feathers will wash off, and the pale blue areas around them will start to get darker. Leave the paper in the water for a few minutes, then place it between two dry tea towels with a heavy book on top to help remove the water and keep it flat. Leave it for a few hours to dry.

In summary...
The paper is covered in chemicals that start to react together when activated by ultraviolet light. As they react, a deep blue compound forms. But the reaction doesn't take place under the feather, so when the original chemicals are washed off, the shapes appear clearly.

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Where did the Huygens probe land?

a) **Saturn's moon Titan**

b) **Earth's Moon**

c) **The Sun**

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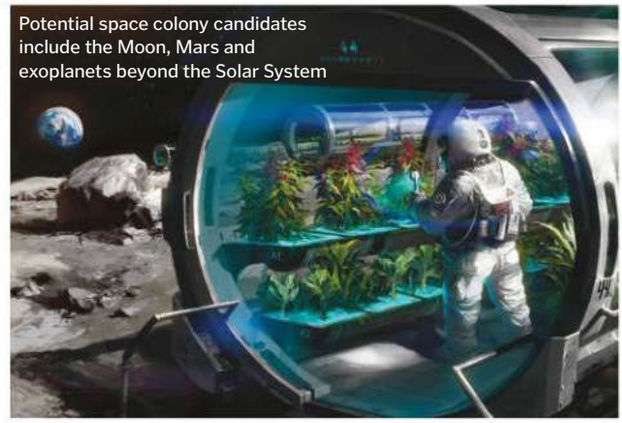
Letter of the Month

Will we ever leave Earth?

Dear **HIW**,
I absolutely love your magazines, as they are packed full of amazing scientific facts! In issue 94 I loved reading the article about sharks and I was astonished (and relieved) to find out that the odds of being killed by a shark are 1 in 3,700,000! I also thoroughly enjoyed reading about 'how marbles are made', as I have a very extensive collection of marbles and it was fascinating to read how they are actually created. My question for you is: do you believe that humans will ever be able to live on a planet other than Earth? Thank you very much for reading this letter.
Yours sincerely,
Lucy Underwood (aged 13)

If humans are ever to live on another planet permanently, there are a number of hurdles to clear. First and foremost, we'll need to devise a propulsion system that could reach habitable celestial bodies in a feasible time frame. The planet or moon chosen must also have suitable conditions to support human life, such as liquid water, a supply of oxygen and survivable temperatures. And we also need to create a clever way of protecting our future colonists from harmful radiation, which we're fortunately sheltered from here on Earth. Developments in engine designs, robots and new spacecraft, as well as increased funding for future missions, are increasing the likelihood of human colonisation of other planets, with several agencies and companies looking to send humans to Mars in the next few decades.


Potential space colony candidates include the Moon, Mars and exoplanets beyond the Solar System

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@ ProfBrianCox
Just watched @Virgingalactic Spaceship 2 land after test flight - beautiful aircraft :-)

@ kristawelz
Build your own #hologram projector! Via @HowItWorksmag #makered #makerspace

Why do we get goose bumps?

Dear **HIW**,
I love reading your magazine, I find it so interesting! There is so much stuff in there I wouldn't know if I didn't read it! Here's my question: what are goose bumps and what is their purpose? I would love it if you could answer my question!
Josh (aged 12)

Goose bumps are bumps on the skin that are caused by an uncontrollable response to cold temperatures or strong emotions. The sympathetic nervous system triggers the contraction of arrector pili muscles, raising the hairs on our skin. This was much more useful to our evolutionary ancestors than it is to us today, and is a result of our built-in flight or fight response. When threatened, our more hairy ancestors would've looked much more intimidating with raised hair. And the system also more effectively retained heat to help keep them warm.


A goose's skin is similar to human hair follicles after its feathers are plucked

The birth of planet Earth

Dear **HIW**,
I wanted you to know that even though I am all the way in Australia, I love getting a subscription to your magazine. I have a question for you! I would like to know how do we know how old Earth is, and how old is it? Thank you!
Alyce Keegan

The age of the Earth is estimated via a combination of geological study and radiometric dating. Many of the oldest rocks on Earth have been destroyed and then replaced by the constant movement of plate tectonics, but fortunately some very old rocks still exist. Inside these rocks are elements that have undergone very slow radioactive decay, and we can measure this decay to see how long it has taken these isotopes to get there. These studies have led to the current estimate we have for the age of our planet: around 4.5 billion years.


Scientists estimate that the Moon formed shortly (relatively speaking) after the Earth

How fast are we running out of fossil fuels?

Dear **HIW**,
How It Works is my favourite magazine and I always read the latest issue, which really feeds my mind. I am wondering when will the Earth run out of its oil and gas resources? Will we run out of fossil fuels before we make a successful transition towards alternative, renewable sources of energy?
Adil Babayev

Fossil fuels have been extracted from the Earth and used as the human race's primary energy supplies since the Industrial Revolution. It is estimated that known oil reserves will run dry around 2052, and natural gas by 2060 as its use is increased to fill the void left by crude oil. Coal will last until approximately 2088, but that may be sooner if demand increases with rising populations, or later if more reserves are found. The transition to cleaner, renewable power is underway though, and in 2015, 25 per cent of Britain's electricity was generated by renewable energy technologies.


Developing and improving methods to harness energy from renewable sources will reduce our fossil fuel dependence

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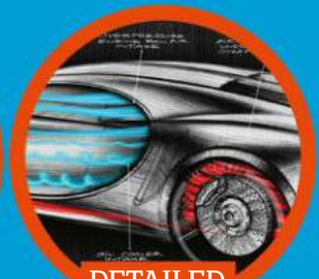
NEXT ISSUE

Issue 98 on sale 20 April 2017

HOW TO BUILD A SUPERCAR

Go behind the scenes at a supercar factory

PRECISION ENGINEERING



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FAST FACTS

Amazing trivia to blow your mind

THE AVERAGE TEMPERATURE ON EARTH HAS INCREASED BY AS MUCH AS 0.8°C OVER THE PAST CENTURY

$651 HOW MUCH EACH US CITIZEN WOULD GET IF APPLE DIVIDED OUT ITS WORTH EQUALLY

34,000

NUMBER OF SWISS ARMY KNIVES PRODUCED BY THE COMPANY VICTORINOX EVERY DAY

400°C

THE TEMPERATURE OF A MIG-25'S FUSELAGE WHEN FLYING AT MACH 2.5

$30

THE AMOUNT JACOB SHALLUS WAS PAID TO WRITE OUT THE US CONSTITUTION

25,000

FRENCH CASUALTIES AT THE BATTLE OF WATERLOO

THE BRAIN CONTAINS AROUND 86 BILLION NEURONS

44

THE NUMBER OF MEN WHO HAVE SERVED AS PRESIDENT OF THE UNITED STATES

12%

THE EFFECTIVENESS LOST BY A HEATING ELEMENT WITH JUST A 1.6MM COATING OF LIMESCALE

5.5 MILLION ESTIMATED NUMBER OF VENDING MACHINES IN JAPAN

ONLY 90 OF THE 118 ELEMENTS IN THE PERIODIC TABLE ARE NATURAL: HUMANS MADE THE OTHERS

20

THE AMOUNT OF PECKS A WOODPECKER CAN COMPLETE IN ONE SECOND

20 MINS THE ESTIMATED TIME IT TAKES FOR YOUR BODY TO PRODUCE ITS DAILY VITAMIN D WITH EXPOSED ARMS AND LEGS ON A SUNNY DAY

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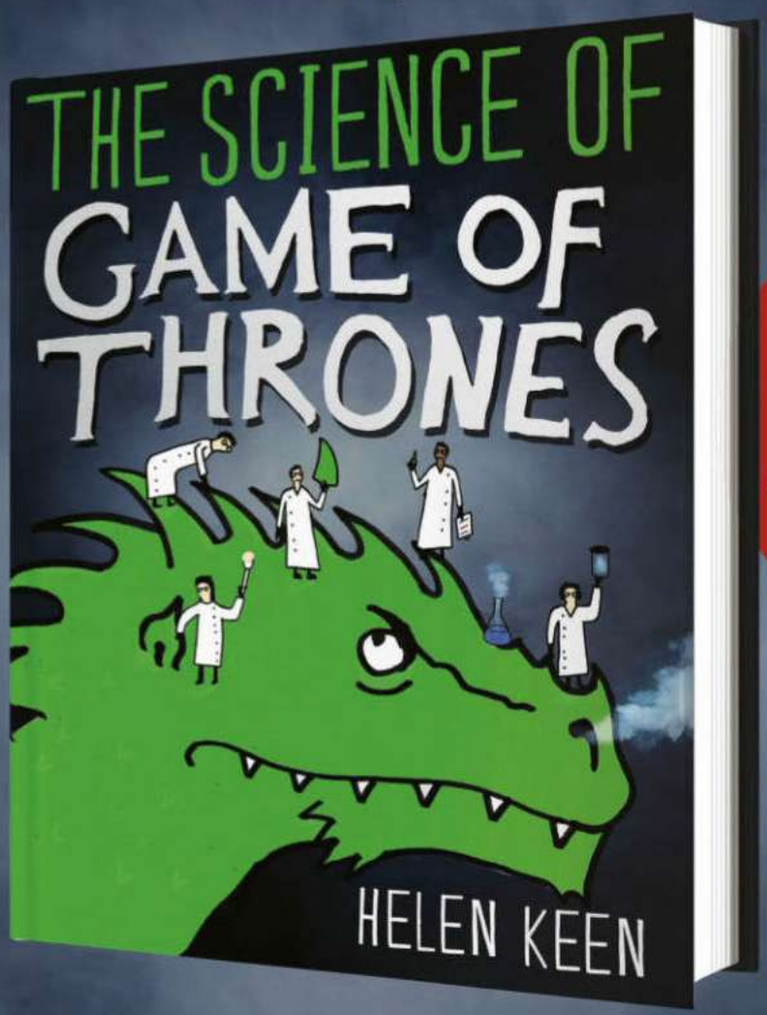

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